COVERAGE AND QUALITY OF POTABLE WATER SUPPLY AND SANITATION IN RURAL AREAS OF DAMOT SORE WOREDA, WOLAITA ZONE, SOUTHERN ETHIOPIA

MASTER OF SCIENCE THESIS

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Dedication

I dedicate this to my entire family of father, mother, brothers and sister and all friends. It also goes to all the people of the developing world who at this moment lack access to potable water.

Statement of the author

I, Meseret Bekele, hereby declare that this thesis: "***Coverage and Quality of Potable Water Supply and Sanitation in Rural Areas of Damot Sore Woreda, Wolaita Zone, Southern Ethiopia***" is my own work and has not been submitted for any degree in any other university. It is being submitted for the degree of Master of Science in Water Resources Engineering and Management at Hawassa University, and all sources of material used for this thesis have been dully acknowledged.

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Acronyms

APHA	American Public Health Association
BOH	Bureau of Health
BOWI	Bureau of Water and Irrigation
CFU	Colony Forming Unit
CSA	Central Statistical Agency
DSWANRO	Damot Sore Woreda Agriculture and Natural Resource Office
DSWWMEIO	Damot Sore Woreda Water, Mines, Energy, and Irrigation office
DSWHO	Damot Sore Woreda Health Office
EC	Electrical Conductivity
EPA	Environmental Protection Agency
ES	Ethiopian Standards
FDRE	Federal Democratic Republic of Ethiopia
GIS	Geographic Information System
GPS	Global Positioning System
HDW	Hand Dug Well
JMP	Joint Monitoring Programme
MDGs	Millennium Development Goals
MOH	Ministry Of Health
MoWR	Ministry of Water Resource
NGOs	Non-Governmental Organizations
NTU	Nephelometric Turbidity Unity
SNNPR	Southern Nation, Nationalities, and Peoples Region
SPSS	Statistical Program for Social Science
SS	Spring Spot
SW	Shallow Well
TDS	Total Dissolved Solids
TC	Total Coliform
UAP	Universal Access Plan
UN	United Nations

UNDP	United Nation Development Programmes
UNEP	United Nations Environment Programme
UNICEF	United Nations International Children‘s and Emergency Fund
WHO	World Health Organization
VIF	Variance Inflation Factors
WSS	Water Supply and Sanitation
WZHO	Wolaita Zone Health Office
WZANRO	Wolaita Zone Agriculture and Natural Resource Office
WZWMEIO	Wolaita Zone Water, Mines Energy and Irrigation Office

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Abstract

Limited access associated with poor potable water supply, sanitation and hygiene make the community to depend on unsafe and poor water consumption and these calling for the expansion and improvement of basic water supply and sanitation services. This study was conducted in Damot Sore Woreda, Southern Ethiopia to examine coverage and quality of potable water supply and sanitation. For this study, four Kebele administrations were selected by purposive sampling technique and 83 households were randomly selected for primary data sources. Household surveys, key-informant interview and personal observations were used for primary data collection. Location map, water quality sampling point and spatial distribution of water supply schemes in the Woreda were prepared using Arc GIS 9.2 software. A total of 55 water samples were taken and examined for physico-chemical and bacteriological parameters;11from source,11 from household containers,11 from drinking cup,11 for dry and 11 for wet season. The data from the respondents were analyzed using descriptive and inferential statistical technique. Accordingly, multiple linear regression models was applied to identify factors influencing the HH water coverage, one way ANOVA were employed to see the statistical difference of the variables at 5% significant level and correlation was also used to observe associations of variables. The findings revealed that the major problems regarding drinking water were: low coverage (46.5%), low spatial distribution of water points(58.4%), low quantity(average 6.9litres) consumption per capita and almost all residents take less than 20 litres of potable water and long fetching time (average 52.75 minutes). It was observed that, HH water coverage is influenced by family size (p=0.00), functionality of the schemes (p=0.014), time required to fetch water (p=0.00) and distance to the schemes (p=0.01) was found to be significant. The result of water quality test revealed that average values for all selected physico-chemical parameters such as pH (except hand dug well at Shamba kebele), EC, Turbidity(except hand dug well, on-spot spring and hand dug well at Bolela, Anchito and Shamba kebeles, respectively), TDS, TH, Nitrate, Iron, Fluoride, Magnesium and Chloride at source, storage and point of use were found within the acceptable limit of ES and WHO. However, the mean value of Temperature and Phosphate were beyond the recommended ES and WHO standards. The laboratory result of bacteriological water quality for all sampled sites exceeded to the ES and WHO standards. The value of temperature decrease significantly from water source to HH storage (p=0.036). However, other parameters showed no significant change from source to storage. The concentration of total coliform increases significantly from supply source to point of use (p=0.024). The dry and wet season measurement showed that variation in physico-chemical and bacteriological parameters. However, statistically no significant difference observed between dry and wet season in all parameters studied. Lack of improved pit latrine, poor hand washing practice, improper handling and disposal of wastes and lack of clean storage facilities identified as the major factors responsible for poor sanitation situation, which contributes to the deterioration of drinking water quality in the Woreda. So, Woreda water supply service could not meet domestic water consumption (l/c/d) with existing capacity and gets lower. The water sources in the area are bacteriologically contaminated and therefore not suitable for domestic purposes unless treated.

Key words: *water supply, water quality, dry season, wet season, sanitation, Damot Sore.*

1. INTRODUCTION

1.1. Background and justification

No other single intervention is more likely to have a significant impact on global poverty than the provision of safe water. Water is a central theme, which can be used to achieve millennium development goals (MDGs) (Schuster Wallace et al., 2008). Water is a natural resource of fundamental importance. It supports all forms of life and creates jobs and wealth in the water sector, tourism, and recreation. As global slogan, “Water is Life” implies that water is one of the critical life need for a human being. Without water, life as it exists on our planet is impossible (Asthana and Asthana, 2001).

Water supply and sanitation are two of the most important sectors of development. Development of community water supply and sanitation results in improved social and economic conditions and improved health (Davis et al., 1993). The benefits of improved water supply and sanitation are many. Including prevention of disease, improved basic health care, better nutrition, increased access to institutions such as health centers and schools, improved water quality, increased quantity of and access to water, reduction in time and effort required for water collection, promotion of economic activity, strengthening of community organization, improvements in housing and ultimately improved quality of life (Okun, 1988).

As the world urban and rural population suffering from water, access to basic sanitation is also a challenge to these groups of world population. Africa has the lowest water supply coverage of the global regions and is second to Asia in terms of lowest sanitation coverage in which 62% of the population has access to improved water supply and 60% have access to improved sanitation (UNICEF, 2006).

In Africa, 602 million people had access to improved drinking water sources in 2006. This shows coverage increased from 56% in 1990 to 64%. The rate at which Africans gained access to improved drinking water sources, 245 million people since 1990, falls short of that required to meet the 2015 MDG drinking water target (Haysom, 2006). The key to increase human productivity and long life is good quality of water. The provision of good quality drinking water is often regarded as an important means of improving health. Although, some parts of the world are making encouraging progress in meeting this Millennium Development Goals, serious disparities remain. Lack of access to improved drinking water is still a serious problem in large portions of Asia and Sub-Saharan Africa (WHO and UNICEF, 2004).

Even though, Ethiopia is a country with high ground water potential that has twelve major river basins, including the Blue Nile and eleven major lakes, which makes the country the “Water Tower” of East Africa. Yet, access to safe drinking water supplies and sanitation services in many parts of the country is among the lowest in Sub-Saharan Africa. While governmental and non-governmental organizations have been implementing water supply and sanitation projects in recent years, many lack sustainability due to improper management. This fact attributed to the service delivery modalities adopted by financers and implementing agencies (Yewondwossen, 2012).

Damot Sore Woreda is characterized by potential surface water source having a number of rivers and springs. There are different rivers originating /crossing the Woreda like Xagacha, kuliya and Mere are some of the rivers in the area. There is a huge ground and surface water potential in the Woreda. Despite the ground water supply potential of the Woreda, it is not possible to construct enough water schemes in all Kebeles. Even in Kebeles where there are improved water schemes, the water supply is not adequate for all and the functioning schemes themselves are not providing reliable and adequate services for different reasons to respective communities (DSWWMEIO, 2016).

This study was conducted in Damot Sore Woreda, Wolaita zone, SNNP Regional State, the water supply and sanitation challenges are still untouched and unsolved problems. The investigator considered from his observation and experience that the problem of water in Damot Sore is growing from time to time. Improving the water supply coverage and evaluating from source to point of use and seasonal variation of water quality has a number of advantages for the society of the Woreda as well as for the government socially and economically.

1.2. Statement of the problem

Ethiopia ranks among the lowest countries in the world in levels of safe water and sanitation coverage 66% of Ethiopia’s 83 million citizens do not have access to an improved water supply and 79% lack access to basic sanitation. The majority of Ethiopia's citizens live in rural areas where rates of coverage are even worse. Among rural Ethiopians, only 34% have access to an improved water supply (Water access in Ethiopia, 2013).

Damot Sore is one of the Woreda found in rural Ethiopia, where the community does not have access to potable water and basic sanitation. Thus, the communities are forced to use water from unprotected water sources, which they may share with their animals. Access and coverage of potable water supply and sanitation services are supposedly very sounding problem in study area. It was observed that there are several factors in the community that were likely resulting in water contamination at sources or during collection, storage and point of-use in household level. In addition, seasonal variation also had impact in water quality based on the public complaint. These factors called for question the basic assumption that water will remain safe from the time it leaves the tap to when it is consumed. If this assumption is shown to be faulty, it would have implications for future development strategies focused on water quality.

The other major problems related to water, sanitation and hygiene in the study area are lack of awareness of people and microbiological pollution. Moreover, pesticides used in agricultural fields impose additional burden in the study area. Diarrhea, gastroenteritis, malaria, typhoid, and hepatitis are the most prevalent water associated communicable diseases in the study area that varies from season to season (DSWHO, 2016).

This research work therefore, specifically investigated the water supply coverage, its significant determinants in the households, water quality variation at different point of utilities and time, sanitation situation and the gap associated with water scarcity to initiate intervention measures in order to address the aforementioned problems in Damot Sore Woreda.

1.3. Objectives

1.3.1. Main objective

The main objective of this study is to examine the coverage and quality of potable water supply and sanitation situation in Damot Sore Woreda.

1.3.2. Specific objectives

The specific objectives achieved in this study are:

- To assess the current(2016) provision of water service and identify its significant determinants in the Woreda.
- To evaluate water quality at the source, storage and point of-use (point of consumption) compared to each improved water source observed by using selected physico-chemical and bacteriological parameters.
- To evaluate water quality in dry and wet season to each improved water source observed by using selected physico-chemical and bacteriological parameters.
- To assess the sanitary condition of the Woreda.

1.4. Research questions

In order to address the above issues, the study were attempted to answer the following five research questions:

- What is the present condition of water supply and sanitations services in Damot Sore Woreda?
- Do the rural inhabitants have proper access to safe and adequate water and basic sanitation facility?
- What are the main challenges in the provision of safe water and sanitation services in Damot Sore Woreda?
- Does the water quality in the study area fulfill the established standards?
- What actions should be taken to improve the water supply and sanitation services in Damot Sore Woreda?

1.5. Significance of the study

The result of this study is expected to find out of determinant factors for household water coverage, drinking water quality variation from source to point of use and seasonal variation on water quality in Damot Sore Woreda. It increases the knowledge and up to date information for individuals who are interested to study further on the coverage and is significant determinants', quality of drinking water and sanitation status in the study area. It also serves as a working document to policy makers in the water sector and the non-governmental organizations. Furthermore, it helps to draw possible suggestions and recommendations in order to improve status of water supply, quality of drinking water and sanitation in the study area.

1.6. Scope of the study

The focus of this study is on water supply and sanitation constructed in the rural part of Damot Sore Woreda. This study specifically emphases on evaluation of rural water supply, potable water quality and sanitation. The study area is limited to rural Kebeles in the Woreda. The study covers selected four Kebeles of water supply and sanitation where data generated from selected water supply schemes and household beneficiaries. The main problem that the researcher encountered in the course of this study was lack of adequate information due to improper document handling by the Woreda's Water Office. Due to poor documentation of the data in the offices, it was laborious to get the necessary and relevant information. Because of the absence of in depth previous research on water supply and sanitation in the study area, it was difficult to see parameters thoroughly and to do a comparative study or deal with another side of the previous study. It is also worth mentioning that lack of sufficient amount of money had an objectionable upshot on the study.

2. LITERATURE REVIEW

2.1. Global issue in water supply and sanitation

Since 1970's, there was a consensus that governments and donors should alleviate poverty in rural areas through providing basic needs such as drinking water, which was largely free at least in capital costs. This approach is now labeled as supply driven. The survival and wellbeing of a nation depends upon sustainable development and for this, water supply and sanitation which are ingredients of a healthy and productive life are essential requirements. For the poor people residing in urban slums and rural areas, to achieve a better economic growth rate and higher productivity, priority has to be given to the health of these people, for which provision of public utilities like water supply and sanitation is necessary (Pathak et al., 2002).

Water has always been a very important issue on the United Nations (UN) agenda. When defining the Millennium Development Goals (MDGs), water was also taken into account as one of the aspects for ensuring environmental sustainability. The aim of the UN is to reduce by half the proportion of people without sustainable access to safe drinking water by 2015 (UNICEF, 2006). The UN says guaranteeing a proper water supply is vital to eradicating poverty. It says the absolute daily minimum amount of water a person needs is 50 liters, which include 5 liters for drinking, 20 for sanitation and hygiene, 15 for bathing and 10 for preparing food. However, because of scarcity, millions of people try to exist on 10 liters a day. Achieving these goals requires sustainable economic and social development in developing countries. However, also notes that most of the constraints to development increasingly tied to water (WHO, 2003).

The consumption of unsafe water contributes to about 2.2 million deaths annually. The amount of disease and lost person-hours due to unclean water is vastly greater than the cost of improving water systems (WHO and UNICEF, 2008). Although only one of the MDGs directly relates to water, improved water management can make significant contributions to achieving most of the other goals. Inadequate supply of water has therefore been identified as one of the central causes of poverty in developing countries as it affects their basic needs, health, food security and basic livelihoods. Much of sustainable development therefore focuses on getting people out of poverty, while improved access to adequate and safe water has been shown to make a major contribution towards poverty alleviation (Katte et al., 2003).

Inaccessibility of safe water and adequate sanitation facility strengthens the cycle of disease, poverty and weakness; therefore, water and sanitation programs are instrumental in efforts to rescue people from poverty. In other word, provision of water and sanitation should be indispensable parts of the poverty reduction strategies applied by developing countries. In the developing world today, poor access to safe water and adequate sanitation continues to be a threat to human health. Expanding access to basic water supply and sanitation, integrated with hygiene education can reduce the burden of water-related diseases significantly by improving the lives of a large part of the world's population. Since provision of sanitation breaks the vicious cycle of poverty and initiates a virtuous cycle of economic well-being, it should be a vital ingredient in the poverty alleviation programs (Pathak et al., 2002).

According to the JMP (2010), Africa has the lowest total water supply coverage of any region, with only 62 percent of the population having access to improved water supply. The situation is worst in rural areas, where coverage is only 47 percent. Around 2.6 billion people do not have access to basic sanitation; and because of poor access to basic sanitation 1.5 million peoples die each year. Many of these people live in south East Asia and sub-Saharan Africa. Sanitation coverage in Africa also is poor, only 60 percent of the total population in Africa has sanitation coverage, with coverage varying from 84 percent in urban areas to 45 percent in rural areas.

2.2. Water supply

2.2.1. Water supply in Ethiopia

Access to water supply in Ethiopia is amongst the lowest in Sub-Saharan Africa and the entire world. While access has increased substantially with funding from external aid, much still remains done to achieve the millennium development goal of halving the share of people without access to water and sanitation by 2015, to improve sustainability and to improve service quality (WHO and UNICEF, 2008). Provision of safe and sufficient water supply and adequate sanitation services are indispensable components in the sustainable development of Ethiopia's urban and rural socioeconomic wellbeing. At present, most of the population does not have adequate and safe access to water supply and sanitation (WSS) facilities. As a result, over 70% of the contagious diseases in the country are water borne/based diseases. Source of most of these diseases could be traced back to inadequate WSS facilities (MoWR, 2001). Ethiopia has been trying to supply potable water to its population, without great success, for more than a century. While water for agricultural use has attracted high levels of investment, water resource management for domestic supply has been relatively neglected, especially before the post imperial period. Even today, rural water supply programs, which affect the majority of the country's population, have not been given sufficient attention (Rahmato, 1999).

The water distribution systems in the country are generally inadequate. The problem is associated partly with unfavorable topography, seasonal fluctuation of the water reservoirs, low capital investment, and lack of efficient water governance among concerned authorities. Quite frequently Ethiopian planners emphasize the agronomic, engineering, or technical aspects of water projects, while giving less attention to governance and participation of stakeholders (Rahmato (1999). Rahmato (1999) also observed that among the main reasons given for the slow progress in water supply services in the 1980s (but still relevant today) are the lack of comprehensive water legislation, inadequate investment resources, and the lack of a national water tariff policy.

The Ministry of Water Resources (MoWR) estimates that 33% of water supply schemes in Ethiopia are non-functional at any time, with negative impacts on coverage and universal access due to lack of funds for operation and maintenance, inadequate community mobilization and commitment and a lack of spare parts (Moriarty et al., 2009).

However, the paradox is Ethiopia has 12 major river basins, the total annual runoff from these basins is estimated at about 122 billion cubic meters (MoWR, 2001). Although a comprehensive national ground water resources study has not been conducted, some surveys suggest that the ground water potential in many parts of the country is high (UNDP, 2005). The results of lack of safe water supply are not sickness and death, but also economic crises. Therefore, safe drinking water is an essential component of primary health care and is vital for poverty alleviation. Introducing improved water supply sources at the household level enhance personal and community knowledge as well as awareness of the importance of other factors, such as hygiene and sanitation (Dagnew et al., 2007).

2.2.2. Water supply in SNNPR

Access to water supply in SNNPR has been steadily improving over the past two decades. In the SNNPR region there are about 12,079 water supply schemes operating throughout the region including 903 spring with distribution, 5,710 spring on spot, 4,854 shallow wells (including hand dug wells fitted with pump), 604 deep bore hole with distribution and 8 surface water based pumped water supply systems constructed by the regional government and NGOs in recent years. The predominant water supply technology used in SNNPR is on-spot spring approximately 31.7% of the population with access to safe water supplies in rural area is served by spot spring followed by shallow wells which is 31.2%. The functionality rate for improved water supply in SNNPR is reported to be 72.95% in rural water supply schemes. However, it has been noted that about 27% of the water supply schemes are non-functional at any given time. The causes for non-functionality are; technical break down (45%), low yield (21%), management/financial problem (20%) and others like water quality (14%) (BoWI, 2016).

However, lack of sustainability of project aggravated the existing poor coverage of water and sanitation implying negative impacts on coverage and on the attainment of the plan. At the end of 2005, access to water supply for rural part of SNNPR was 38.7%. However, due to the efforts made by governmental and non-governmental organization, the number of people with access to potable water supply increase from 38.7% to 58.7%, at the end of 2014 (BoWI, 2016).

2.2.3. Water supply in Wolaita Zone

Wolaita zone is located in the southwest part of the region. Access to safe water supply is 61.5% coverage rate for rural areas up to 53 % with per consumption rate of 15liter/capital/day within 1.5km and towns' kebele water coverage up to 71 % within per consumption rate of 20 liter/capital/day with in 0.5km, the non-functionality rate in rural area is 27.26% (WZWMEIO, 2016). These supply systems are constructed by different organizations such as governmental and non-governmental organizations at different times. Totally available water supply schemes in the Zone are;-

Table 2-1 Existing water supply schemes in Wolaita zone **(**Source; WZWMEIO, 2016).

Water supply schemes	Hand dug well	Rope pump	Shallow well	On spot spring	Borehole	Spring with distribution
No	184	85	308	362	69	178

2.2.4. Water supply in Damot Sore Woreda

As indicated by the Zonal and Woreda water Office, there is a huge ground and surface water potential in the Woreda. Despite the ground water supply potential of the Woreda, it is not possible to construct enough water schemes in all Kebeles. Even in Kebeles where there are improved water schemes, the water supply is not adequate for all, and the functioning schemes themselves are not providing reliable and adequate services for different reasons to respective communities. The water coverage of the Woreda is about 48%. Only 56,087 beneficiaries are getting access to safe water and the rest of the population about 60,760-use unsafe water from unprotected water source like spring, and rivers (DSWWMEIO, 2016). It was observed that no coordination, collaboration, and partnerships amongst non-state actors and government WaSH sectors in water access. Due to this reason; 31% of water schemes are non-functional, 59% of schemes cannot cover operation and maintenance costs, 66% of the scheme catchments are poorly managed and water scheme committees are not well equipped to effectively manage water schemes (DSWWMEIO, 2016).

These supply systems are constructed by different organizations such as governmental and non-governmental organizations at different times. Totally available water supply schemes in the Woreda are;-

Table 2-2 Existing water supply schemes in Damot Sore Woreda **(**Source; DSWWMEIO, 2016).

Water supply schemes	Hand dug well	Spring with distribution	Shallow well	On-spot spring	Borehole	Others
No	10	3	19	31	3	13

2.3. Water sources and sanitation classifications

Water for drinking purpose can be found from natural sources like surface water, ground water, and rainwater. Water from all these sources to use for household activities need treatment based up on their impurities. However, the treatment and the degree of cleanness of the water make the water safe or unsafe to drink. WHO and UNICEF classified water sources as improved and unimproved based on their purity to drink (JMP, 2006).

Table 2-3 Elaborates the improved and unimproved water sources (Source: JMP, 2006).

Water supply		Sanitation	
Improved	Unimproved	Improved	Unimproved
-Household connection -Public standpipe -Borehole -Protected dug well -Protected spring water -Rainwater collection	-Unprotected well -Unprotected Spring -Vendor-provided water -Bottled water -Tanker-truck provided	-Connection to a public Sewer -Connection to a septic System -Pour-flush latrine -Simple pit latrine -Ventilated improved pit Latrine	-Service or bucket Latrines -Public latrine -Latrines with an open pit

2.4. Rural water supply system and technology

Rural water supply(RWS) systems can be defined by type of management and governance, which is often community based and derived from social rules and socially agreed up on modes of operation (Brooks, 2002). Approximately 40% of rural Ethiopia still lacks access to clean water despite rigorous effort made by the Ethiopian government to increase water supply in the country. It provides potable water to rural community for domestic uses (for example, drinking, cooking, bathing and hygiene), and for livestock and requires the supply of high quality water on a continuous basis replacing the former water supply sources the unprotected ones (Dagnew et al., 2007). Some of the infrastructure features of a RWS in the study area include hand dug well, springs, borehole, shallow/medium wells and roof rainwater catch tanks (DSWMEIO, 2016).

2.4.1. Hand dug well

A hand dug well is a type of water well which is constructed by digging by hand and it is the most widely used method of well-constructed in many rural area of the world. Hand dug wells (HDWs) are a common technology employed for rural water supply because of its relative ease in construction, low cost input and its familiarity to most communities. Nowadays, the technology has been modernized by using better linings and more pumps that are efficient in order to improve a well’s performance. HDWs are shallow ranging in depths up to 20 meters and approximately 1.5 meters in diameter, which accommodates the digging process. These wells most often are dug down to tap water stored in perched water tables, clay, or other impermeable layers on which percolated water collects above the main water table. The addition of a lining to the HDWs decreases the likelihood of a well collapsing and excessive loss from seepage (Water Aid, 2011).

2.4.2. Spring

A spring is a place where ground water naturally is released from the earth's surface. Spring water typically moves downhill through cracks and fissures in the bedrock until the grounds surface intersects the water table. They are usually used as water supplies and can be a reliable and relatively inexpensive source of drinking water if they are developed and maintained correctly. Spring located toward the top of the water table tend to dry out as the water table lowers during the dry season. There are many different types of springs falling under two categories according to the condition under which water flows to them: gravity springs and artesian springs (Water Aid, 2010). Groundwater seeping from the ground to the surface at springs provides an excellent water supply source if it is developed appropriately and remains free from pollution. Low flows coincide with the very beginning the rainy season or at the end of the dry season output (Achadu et' al, 2013). According to Water Aid (2011), a flow of 0.1 liters per second (Lps) would result in a daily flow of about 3,000 liters which would supply a community of 150 people with their water requirements (20L per person per day).

2.4.3. Medium/Shallow well

Shallow wells are deeper than 30 m but lesser in depth than boreholes, which are much deeper (up to > 100m) and have a smaller diameter, approximately 100 to 150 mm. Shallow wells often reach the main aquifer where sufficient water can obtained. However, pumping is the only option to extract the water from these wells. Similar to HDWs, a medium/shallow well will have an internal lining, an apron and cover for situating a pump. The actual excavation of the well is the challenge (Water Aid, 2011). Poorly designed and constructed well will quickly become expensive to maintain and eventually unstable, possibly even collapse. In order to design a deep shallow well a general understanding of water occurrence and movement through rocks (science of hydrogeology) is important. According to Harvey (2007) for shallow and medium wells to be sustainable there need to be active community mobilization in site selection, during drilling, post drilling, installation and management otherwise this can have a significant negative impact on poor rural communities, particularly in the dry season when alternative water source are scarce.

2.4.4. Hand pumps

A hand pump is composed of a pumping arm, a piston or plunger, valves, pump rods and pump cylinder. The arm is pumped by hand and drives the piston and pump rods up and down within the pump cylinder causing the different valves positioned above and below the piston to open and close depending on whether water is being pulled in or pushed up (Water Aid, 2011). Hand pumps are installed on hand-dug, shallow and deep wells in order to lift water from below the ground surface to the users at the surface. There are several types of hand pump exist and used throughout rural Ethiopia (MoWR, 2001).

2.5. Accessibility of Water

According to WHO (2008), access to safe water is the share of the population with reasonable access to an adequate amount of safe water. Safe water includes treated surface water and untreated but uncontaminated water such as from springs, medium/shallow wells and boreholes. In rural areas the water source a shallow well, hand dug and protected on-spot spring not more than 1.5km away from households. An adequate amount of water is that which is needed to satisfy metabolic, hygienic and domestic requirements usually about 15 liters of safe water per person per day. This minimum quantity, however, vary depending on whether it is an urban location or rural and whether warm or hot climate. Perhaps this is why the WHO (2008) described basic human water need to be 20 to 50 liters of uncontaminated water daily.

2.6. Water quality

Apart from quantities consumed, water quality compromised by various factors that require measurement. Some factors such as physical, chemical and bacteriological processes because the quality of surface water to vary during the years (WHO, 2010). Water quality is a measure of the condition of water relative to the requirements of one or more biotic species and to any human need or purpose and it is most frequently used by reference to a set of standards against which compliance can be assessed. Monitoring the quality of water facilitates; evaluation of nature and extent of pollution, effectiveness of pollutant control measures, water quality trends and prioritization of pollution control efforts (Diersing-Nancy, 2009). The available sources for a potable water supply are groundwater and surface water. Therefore, it should be protected, used and maintained in an appropriate way. There are several parameters used to determine the suitability of water and the health contaminants such as microbiological, physical, chemical, and microscopic examinations, which may be found both in untreated and treated water.

To provide safe water, there is a need to ensure that the quality of drinking water assessed and monitored. Even a personal preference such as taste is a simple evaluation of acceptability. Drinking water qualities assessed by comparisons of water samples to drinking water quality guidelines or standards. These guidelines and standards provide for the protection of human health by ensuring that clean and safe water is available for human consumption (WHO, 2008).

2.6.1. Physico-chemical water quality aspects

Physico-chemical parameters are the physical and chemical parameters associated with water which have an influence on its quality and also affect the biological constituents of the water (Diersing-Nancy, 2009).

Temperature in analysis of the physico-chemical quality of water samples, temperature considered as a critical parameter. It has an impact on many reactions including the rate of disinfectant decay and by-product formation (Volk et al., 2002). An aesthetic objective is set for maximum water temperature to aid in selection of the best water source or the best placement for a water intake. It is desirable that the temperature of drinking water should not exceed 15C^{o} because the palatability of water is enhanced by its coolness. In addition to cool water tasting better than warm water, temperatures above 15 degree Celsius can speed up the growth of nuisance organisms such as algae, which can intensify, taste, odour and colour problems. Temperature also affects water treatment. If nutrients are available, the microbial activity (as measured by heteroplate count) increases significantly at water temperatures above 15ºC in the absence of a disinfectant residual. Therefore, water supplies generally tend to keep the temperature as low as possible in order to minimize the bacterial growth. Keeping the temperature low reduces the risk for pathogenic proliferation and survival since the optimal temperature for most pathogens is close to the human body temperature (Volk et al., 2002).

PH is one important water quality parameter, the pH of water, affects the biochemical processing water. Most drinking water have a pH from 4 to 9 and the majority are slightly alkaline due to carbonates and bicarbonates of calcium and magnesium dissolved in water with variable pH are most likely contaminated and indicating the introduction of industrial wastes (Hutton, 1996).

Electrical Conductivity (EC) is the electrical conductivity of water a measure of its ability to carry an electric current; the more dissolved ions solutes in a water, the greater its electric conductivity. Conductivity can be regarded as a crude indicator of water quality for many purposes, since it is related to the sum of all ionized solutes or total dissolved solid (TDS) content (Keith, 2004). Pure water is a poor conductor of electricity. Water shows significant conductivity when dissolved salts are presented (Barron and Ashton, 2005). The health Effect of EC will be the function of TDS in the drinking water. MOH (2008) states that, Health effect related to TDS are minimal at concentration below 2,000-3,000 mg/l TDS. In contrast, high concentration of salts imparts an unpleasant taste to water and may adversely affect the kidneys.

Turbidity is a measure of the cloudiness of water and used to indicate water quality and filtration effectiveness. Turbidity of natural water is caused by the presence of compounds such as clay, mud, organic matter, bacteria and algae (WHO, 2003). Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria (APHA, 1998). These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches. Drinking water should have low turbidity since suspended particulates matter provides suitable sites for the growth of bacteria and other microorganism, which have health, risk (Hutton, 1996).

Total dissolved solids (TDS) in waters constitute mainly carbonates, bicarbonates, chlorides, sulfates, calcium, magnesium, potassium, dissolved metals, dissolved organics and other substance account for a small portion of the dissolved residues in water. Dissolved solids and residues in drinking water tend to change the waters physical and chemical nature of drinking water (Cairn cross, 1990; Hutton 1996).

Hardness is measure of concentration of calcium and magnesium salt in water, is important variable for drinking water quality. They are generally present as carbonate and bicarbonate salts. Scaling problem in pipes and utensil makes hard water objected by consumers in addition to its health and taste discomfort. Magnesium is the major contributor to hardness and like calcium, concentration of magnesium above 150mg/l especially if present with sulfate can cause gastrointestinal irritation and diarrhea; some salts of magnesium in water are toxic by ingestion or inhalation, concentration of magnesium greater than 125mg/l also can have a cathartic and diuretic effect (Cairn cross, 1990; Hutton 1996).

Fluoride is found naturally in much water, it is also added in many water systems to reduce tooth decay. Excessive fluoride concentration can cause stained or mottled teeth. This is true where the natural fluoride content is above 2.4mg/l the concentration of fluoride in drinking water is critical when considering the strength of growing teeth and bones (Dagnew et al., 2007).

Chlorine as the chloride ion is the major constituent in water and wastewater with a wide range of concentration from few mg/l in clean rain to10 of mg/l in supersaturated, hot saline ground water. Chloride may be increased in surface water since it is concentrated in human and animal urine reaching watercourses. Human urine may contain 1-1.5% of NaCl. A related health problem of chlorine contamination in drinking water includes Eye/nose irritation; Anemia; Infants and young children: nervous system effects (WHO, 2008).

Nitrates are the most oxidized forms of nitrogen and the product of the aerobic decomposition of organic nitrogenous matter. The significant sources of nitrates are chemical fertilizers from cultivated lands, drainage from livestock feeds, as well as domestic and industrial sources. Natural waters in their unpolluted state contain only minute quantities of nitrates. High nitrate levels in water can cause methemoglobinemia or blue baby syndrome, a condition found especially in infants less than six months. The health effects of nitrate in drinking water are shortness of breath and blue-baby syndrome and other disorders (WHO, 2004).

Iron is one of the most abundant metals in the earth's crust. Iron contamination is a particular problem for anaerobic groundwater supplies, but iron can get into drinking water from the use of iron coagulants or from corrosion of galvanized iron, steel and cast-iron pipes in the distribution system. Iron also promotes the growth of iron bacteria, which oxidize ferrous iron to ferric iron and in the process, corrode the piping and deposit a slimy coating on its surface (WHO, 2004). Some surface waters also have iron problems, particularly related to colloidal iron.

Total chlorine or residual chlorine in areas where there is little risk of a water borne outbreak, residual free chlorine of 0.2 to 0.5 mg/l at all points in the supply is recommended. General system failures, inefficiency in disinfection, poor maintenance are some of factors that affect the quality of water in Ethiopia (Dagnew et al., 2007). Therefore, when water leaves the treatment plant residual free chlorine of about 1mg/l is needed for health reasons and it is recommended that such level be maintained at points of consumption (Momba et al., 2006).

2.6.2. Bacteriological water quality aspects

The most common bacteriological water quality indicators include TC, FC and E.coli. An indicator organism may not necessarily pose a health risk but it can be easily isolated and enumerated, is present in large numbers, is more resistant to disinfection than pathogens, and does not multiply in water and distribution systems (WHO, 2008). Indicator bacteria are used to evaluate the potability of drinking water because it would be impossible to accurately enumerate all pathogenic organisms that are transmitted by water. Coliforms are a group of bacteria with common characteristics used to indicate unacceptable water quality. The presence of any coliform organism in drinking water is used as an indicator of faecal contamination since they are the most sensitive indicator bacteria for demonstrating excretal contamination. Within the total coliforms group, E.Coli bacteria specifically used to indicate faecal contamination Escherichia coli (E.coli), a thermo tolerant coliform, is found to be the most numerous in animal or human faeces of the total coliform group, rarely grows in the environment and is considered the most specific indicator of faecal contamination in drinking water. The presence of E.coli provides strong evidence of recent faecal contamination (Erah et al., 2002).

2.6.3. Water quality standards and guidelines

The World Health Organization (WHO) drinking water quality guidelines provide international norms on water quality and human health that are used as the basis for regulation and standard setting, in developing and developed countries worldwide. These guidelines are adopted by many countries as national guidelines to follow. These countries including Ethiopia set drinking water quality guidelines based on the WHO guidelines but may modify these based on what is achievable in the country.

Table 2-4 Maximum allowable concentrations of water quality parameters for drinking purpose (ES, 2002 and WHO, 2008).

Parameters		Unit	WHO guideline	Ethiopian Standard
Physical parameters	Temperature	^oC	<15	--
	Turbidity	NTU	5	7
	EC	µs/cm	1000	1500
	pH	pH	6.5-8.5	6.5-8.5
Chemical parameters	TDS(mg/l)	mg/l	1000	1000
	Nitrate	mg/l	50	50
	Chloride	mg/l	250	250
	Fluoride	mg/l	1.5	3
	Total Hardness ($CaCO_3$)	mg/l	300	300
	Iron	mg/l	0.3	0.4
	Magnesium	mg/l	50	50
	Chloride	mg/l	250	250
	Phosphate	mg/l	0.005	0.02
Bacteriological parameters	E. Coli/thermo tolerant coliform bacteria	CFU	0/100ml	0/100ml

2.7. Water quality deterioration at different level of utilities

Drinking water has to be wholesome and clean when it becomes available for the consumers. However, from the time water leaves the water works, an array of processes may affect its quality during transport and storage (WHO, 2010). Water quality degradation between the sources and point-of-use may be due to several reasons such as the hygienic condition of the water storage containers and the environment of storage (Trevett et al., 2004). A number of processes may alter water quality during transport and in the distribution system to the consumer/point of use. This may be due to inherent properties of the water which may lead to microbial after growth or corrosion, or to the choice of materials in contact with drinking water which may allow migration of organic materials that can sustain microbial growth or may release heavy metals such as copper, lead or nickel. Finally, leaks or fractures may permit the entry of pollutants such as organic micro pollutants (for example gasoline compounds) or pathogens from surface or wastewaters (Trevett et al, 2004). While it is important to increase access to improved water sources, the assumption that improved sources of water are of microbial quality does not necessarily hold true after the water has been transported and stored in the home. For example, there are opportunities between the water source and the household for the water to become re-contaminated through contact with unwashed hands and further perpetuating the cycle of poor quality drinking water. Household storage containers often allow for recontamination when water is removed using a cup through the opening at the top of the storage container, be it a traditional clay pot or a plastic bucket (Kausar et al., 2012).

Most behaviors related to water collection, storage and use in Damot Sore are not unique to that community. The following common practices have been observed elsewhere worldwide (Trevett, et al., 2004; WHO, 2010); Water collected in open top buckets or jerry cans, Buckets cleaned before use by swirling water and rubbing with a hand, Hand-water contact is common in transit between source and household storage, Water stored in clay pots with loose lids, Water scooped out of clay pots with communal cup, Hand washing not observed and Storage containers are kept in an area that may be shared with animals. While most behaviors related to water are universal, the basis for these behaviors may be derived from different nuances in culture, beliefs and understanding.

2.8. Sanitation

2.8.1. Sanitation in Ethiopia

According to MOH (2008), sanitation refers to the hygienic principles and practices relating to the safe collection, removal or disposal of human excreta, refuse and waste water, as they impact upon users and the environment. Several studies have documented the significant positive effect of sanitation on reducing child diarrhea (Fewtrell et al., 2005). Moreover, improved sanitation has been shown to lower the health risks related to bilharzias, trachoma, intestinal helminthes and other sanitation related diseases. In addition, improved sanitation is likely to reduce the burden of disease related to other major health issues by reducing the average stress level for the immune system, and thus strengthening the resistant to response to new infections. Ethiopia's head of Environmental Health has reported that the current percentage of households with access to sanitation is 28.6 per cent but that 30-80 per cent of the available pit latrines may be non-functional. Though the Millennium Development Goal (MDG) target for sanitation in Ethiopia is to reach 52 per cent of all households, the Ethiopian government has ambitious plans to achieve 100 per cent coverage in hygiene and sanitation by 2012, with their new national hygiene and sanitation strategy and protocol. The protocol is based on three pillars: promoting healthy behavior (advocacy, social mobilization and social marketing); having an enabling social and political environment (political support, public financing and coordination) and access to the necessary products and technology (infrastructure and hygiene products) (Gebreselassie, 2007).

2.8.2. Sanitation in SNNPR

SNNPR had one of the lowest sanitation and hygiene coverage levels in the country, the extent of the regional budget allocated to sanitation and hygiene was amongst the lowest at only 0.4% of the health budget. The scope of education on sanitation and hygiene was at time limited, due to lack of appropriate strategies for community education and mobilization. Messages on sanitation and hygiene communicated, when community members came to health institutions to obtain health services. The approach to sanitation and hygiene was supply driven, with health authorities raising the expectations of households that incentives to improve the practices would be provided by government. The Bureau of health recorded that, therefore, household demand for sanitation and hygiene services had been low (Shiferaw, 2003).

Sanitation coverage is quoted to be 38% in rural areas and 57% in urban areas. In the rural areas, long queues around safe drinking water points are common. Some 60% rural households have access to latrine facilities compared to 80% in urban areas (national figure 63%). Local environmental conditions, such as loose soils, high groundwater tables, floods, termites attacking construction timber, and lack of timber threaten. However, to make the lifetime of latrines short; i.e. questions do arise as to the sustainability of this wave of latrine construction (e.g. need for technical innovative improvements) if HHs are not to drop off the sanitation ladder and stop using latrine (BoH, 2016). Field observation suggest a high rate of latrine use, but reveal still poor hand washing and water storage/handling practices (despite respondents to the survey declaring much higher rates). If the BoH approach is not to be reduced to just ‘latrine counting,’ the behavioral aspects need more effective attention amongst otherwise strong communication campaign. This echoes one weakness in the way messages were communicated, whereby the focus given to coverage responding to the ambitious quotas for latrine construction – diverted attention from latrine utilization and personal hygiene, those being behavioral issues harder to change than hardware (Tefera, 2008).

Government and non-government organization have dedicated considerable resources to improve sanitation and hygiene in southern region. For example, the BoH in 2003 launched a new health care plan to provide quality preventive health services in an accessible and equitable manner to all segments of rural population through a comprehensive Health Extension Program (HEP). One of the focal point of this program is hygiene and environmental sanitation and health extension workers are working at the kebele level in order to promote proper and safe excreta disposal system in household throughout the region (Alula, 2008). Regarding latrine availability, the data from the four welfare monitoring survey reports (2004) shows that the waste disposal facilities of most households 60.57% of the country and 54.12% of SNNPR region was to use wastes as manure whereas 32.06% versus 39.63% respectively practice throwing away to the environment. Despite such figures, latrines are virtually non-existent in rural communities with defecation taking place in fields, bushes or along drainage ditches. The non-functionality of the available latrines estimated to be greater than 80% in the country (Gebreselassie, 2007), which is likely the same in the region. If this trend of non-functionality of sanitation facilities continues, the risk of fecal-oral transmission and the mortality rate of children due to poor sanitation increase.

2.8.3. Sanitation in Wolaita Zone

Improving access to safe water and sanitation facilities leads to improved health in families and communities. However, when people are also motivated to practice good hygiene practices, health benefits are significantly increased. Hand washing with soap can result in major health improvements. One review of studies in Wolaita zone documented a 35- percent reduction in diarrheal morbidity from improved hand-washing (WZHO, 2016). Hygiene is especially important for the survival and development of young children. Good hygiene practices among mothers and other caregivers (especially hand washing with soap after defecating and before preparing food and the safe disposal of children's feaces) prevent diarrhea. Children's feaces are often not disposed of safely even though they are more likely to contain diarrheal pathogens than adult feaces. In Wolaita zone, more than half of households surveyed in rural areas the faces of children less than three years old were not disposed of safely. There is a need to educate the people to dispose off the waste in proper places (WZHO, 2016). The following table shows the status of zonally sanitation capacity.

Table 2-5 Improved sanitation coverage in Wolaita Zone (Source; WZHO, 2016).

No	Woreda's	Population	Household	Improved latrine	
				No	%
1	Damot Sore	116,847	20,160	9845	49
2	Damot Gale	141823	28943	21062	73
3	Duguna fango	122316	24962	8594	34
4	Damot woyide	116566	23789	9199	39
5	Humbo	159393	32529	11979	37
6	Sodozuria	176810	36084	24762	69
7	Ofa	132054	26950	11291	42
8	Damot fulasa	133660	27278	10819	40
9	Boloso sore	196665	40136	25480	63
10	Bolose bombe	111079	22669	6595	29
11	Kindo koysha	133117	27167	16544	61
12	Kindo didaye	123348	25173	16271	65
	Total	1924196	392509	201922	51

2.8.4. Sanitation in Damot Sore Woreda

The quality of water that is well recognized as major transmission route for infectious diarrhea, typhoid and other water borne disease. According to the information obtained from the Woreda water office, the sanitation coverage of the Woreda is 58%, which in turn indicates that most of the population is at risk of communicable disease. Most of this could be preventable by introduction of safe water supply, hygiene and sanitation. Moreover, pesticides used in agricultural fields impose additional burden in the study area (DSWMEIO, 2016). Diarrhea, gastroenteritis, malaria, typhoid, and hepatitis are the most prevalent water associated communicable diseases in the study area that varies from season to season. From the above quantitative WASH baseline data, the practices of sanitation though exist in the Woreda, the implementation is poor as to the data of sanitation and community hygiene (DSWHO, 2016). Hand washing practice with water (and soap or equivalent) is weak. Hand washing facilities are poorly designed and dirty water is often used, with hand washing facilities' not located near the latrine all of which results in dirty hands with high risks of transmission of faecal-oral diseases. Lack of public latrines at gathering places forces people to use open defecation which may undermine their adapted behavior of latrine use at home (DSWHO, 2016).

3. MATERIALS AND METHODS

3.1. Bio-physical set up of the study area

3.1.1. Location and demography

The study area is Damot Sore Woreda of Wolaita Zone, Southern Nation, Nationalities, and Peoples Regional State (SNNPRS) of Ethiopia. It shares a boundary in the Eastern with Sodo Zuria Woreda, in the North with Boloso Sore Woreda, in the South with in Ofa Woreda and in the West part Bolosso Bombe Woreda. The Woreda lies between 06°50’0’’N-07^{0}4’00’’N latitude and 37°35’00"E - E 37°42'30" degree E longitude. The Woreda is located 347 Kms away from the country capital South West of Addis Ababa and 178 Km away from the northeast of regional capital, Hawassa. The altitude of the Damot Sore Woreda is ranges from 1350 to 2200 m.a.s.l. (WZANRO, 2016).

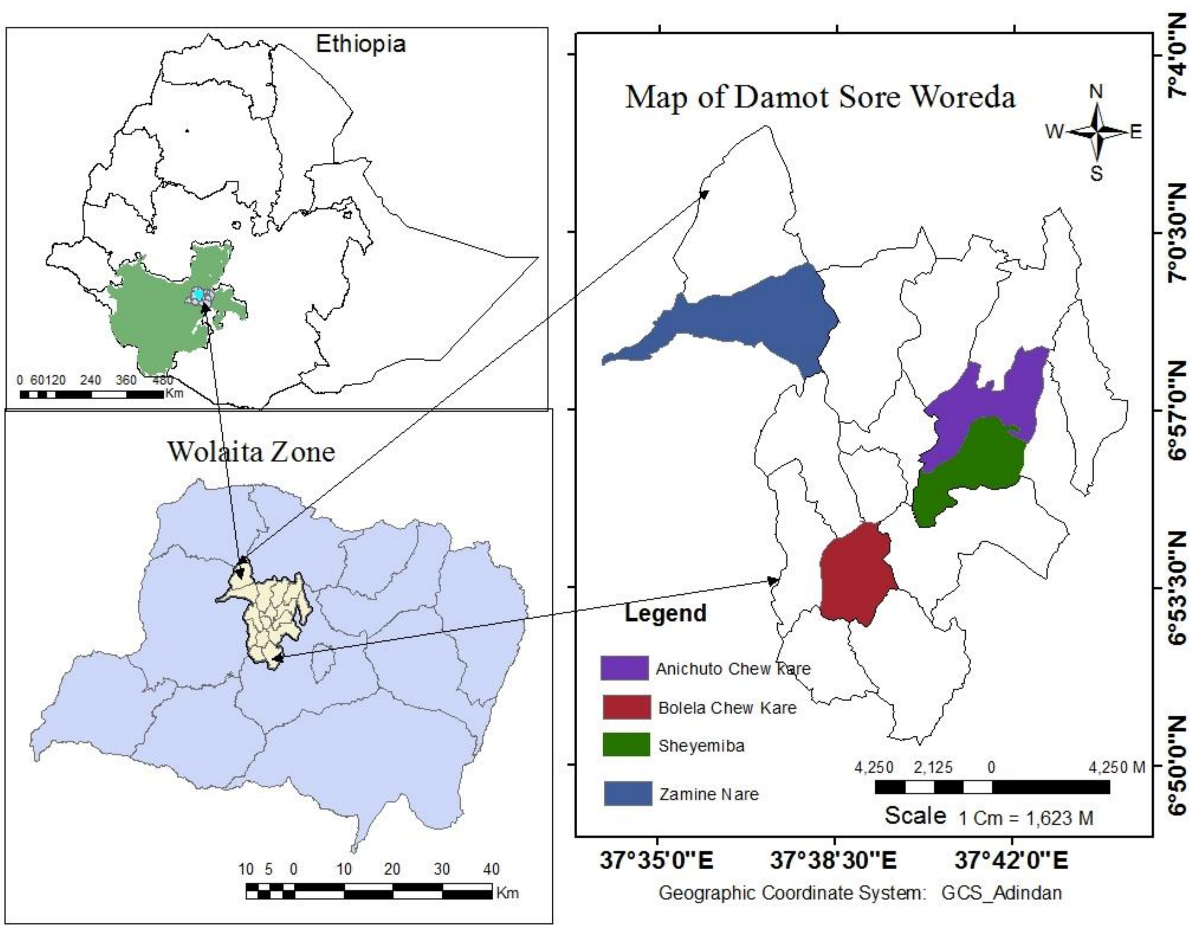

Figure 3-1 Location map of the study area (source; WZANRO, 2016).

The total population of Damot Sore Woreda is 116,847 from which are 59,825 males and 57,022 are females with average family size of 6 persons per household. The majority of the population who are living in the rural areas are 109,682 and urban is 7165 with the annual population growth rate of 2.8% (CSA, 2007).

3.1.2. Climate and rainfall distribution

Damot Sore Woreda is the study area located experiences the average daily temperature of 17.6℃ to 32℃. The rainfall distribution system of the Woreda is bimodal with average annual rainfall between 1100 and 1700 mm. There are three agro-ecologic conditions comprising of 18% kola (lowland), 67% woynadega (midland) and 15 % dega (highland) (DSWANRO, 2016).

3.1.3. Area coverage and livelihood system

Damot Sore Woreda has area coverage of 18,091.34 ha. Among which 18,045.5 ha of area is covered by land surfaces' and 45.8 ha of area is covered by water bodies. Mainstay of almost all population of the area is agriculture. The major crops produced in the area are maize, enset, teff, haricot bean, sweet potato, and root crops. Livestock production is another agricultural activity in the study area (DSWANRO, 2016).

3.2. Data sources and collection instruments

Multiple data gathering instruments employed to collect data for this study. The questionnaires were both close and open-ended questions. The close ended questions were meant to capture direct answers from the respondents, while the open ended questions were to arrive at relevant information that could not be obtained by the close ended questions. The questionnaires were supported by personal in depth interview and transect walk. Structured and unstructured interview, personal observation and document analysis were the principal means of gathering the data used in the study. The researcher supervised and managed the interview of the key informant. Interviewers were recruited and given short-term training, so that they would collect the primary data using structured questionnaires. The water source/points of the Woreda, the spatial distribution of water source/point of the whole Woreda and the study area location were carried out using GPS and Arc GIS software.

3.2.1. Primary data collection

Primary data were collected from the respondents by using household survey, key informant interviews and personal observations (structured and unstructured interview) of water supply and sanitation conditions of the study area.

A. Household survey

For the evaluation of rural water supply systems, four indicators have been taken in to consideration according to the guidelines of WHO (2004). These indicators mainly focused on water quantity and quality supplied to users, the accessibility for continuity supply of the water supply system, convenience of the water sources. In addition to this, access to water supply, operation and maintenance, hygiene and sanitation and community participation were addressed through the questionnaires. The author with the help of assistants physically administered the questionnaires to interview and pretesting was made before the data collection. Totally four research assistants were selected one for each kebele to interview the public. The research assistants were selected based on three criteria a) previous involvement in administering interview, b) Understanding of the local language and c) College/university graduates. The researcher briefed them on the purpose and process of the research, guided them throughout the research process.

B. Key informant interview

Key informants interviews were carried out to collect background information on institutional set up, operation and maintenance, causes of non-functionality of the schemes, coverage of water supply and sanitation situation of the Woreda. The interviews were held with selected individuals of two Woreda and one Zone water office experts who were believed to have good knowledge about the subject matter and experience.

C. Personal observation and site visits

It was employed to observe and record the status of water supply at water points. Photographs were part of the assessment instruments to pick up the status of different water supply schemes. Field observations using structured checklists and unstructured interview administered. Observation can be used as a supportive or supplementary technique to collect data that may complement or set in perspective data obtained by other means. These were basically carried out at the water points and households of the locality. Data for the observation include mainly protection mechanism like presence of fence, guard, appropriate and fixed time of fetching, problems related with service structures, presence of latrine and its situation.

3.2.2. Secondary data collection

Secondary data collected from different data sources such as publications, research documents and reports of various organizations. A detailed literature review of the related documents on water supply system, quality and sanitation made. The purpose of the literature study is to see what have been done before and what the gaps were hitherto so that the researcher able to come up with theories, which used to make analytical generalizations of the empirical data to be collected.

3.2.3. Sampling techniques

For this study, from the 21 rural kebele administrations in Damot Sore Woreda, due to budget and time constraint 20% from the total Kebeles of the Woreda were selected by using purposive sampling techniques for household water use pattern and sanitation.

Damot Sore Woreda has three agro-climatic zones from which 18% was ‘kolla’, 67% was “Woinadega” and 15 % was “Dega.” One sample Kebele were selected proportionally from “kolla” agro-climatic Zone, two-sample kebeles were selected from Woindega whilst the remaining one Kebele was selected proportionally from “Dega” agro-climatic zone by simple random sampling in order to have representative sample based on availability of water supplies and consideration on top of the agro-climatic zonation. Accordingly, four Kebeles were selected for this purpose are Zamine nare kebele from ‘’Kolla’’, Shamba and Anchituchawkare kebele from “Woinadega” and Bolelachawkare kebele from ‘’Dega’’ agro-climatic zonation. Finally, probability proportional sampling techniques used to select the households from each sampled kebeles.

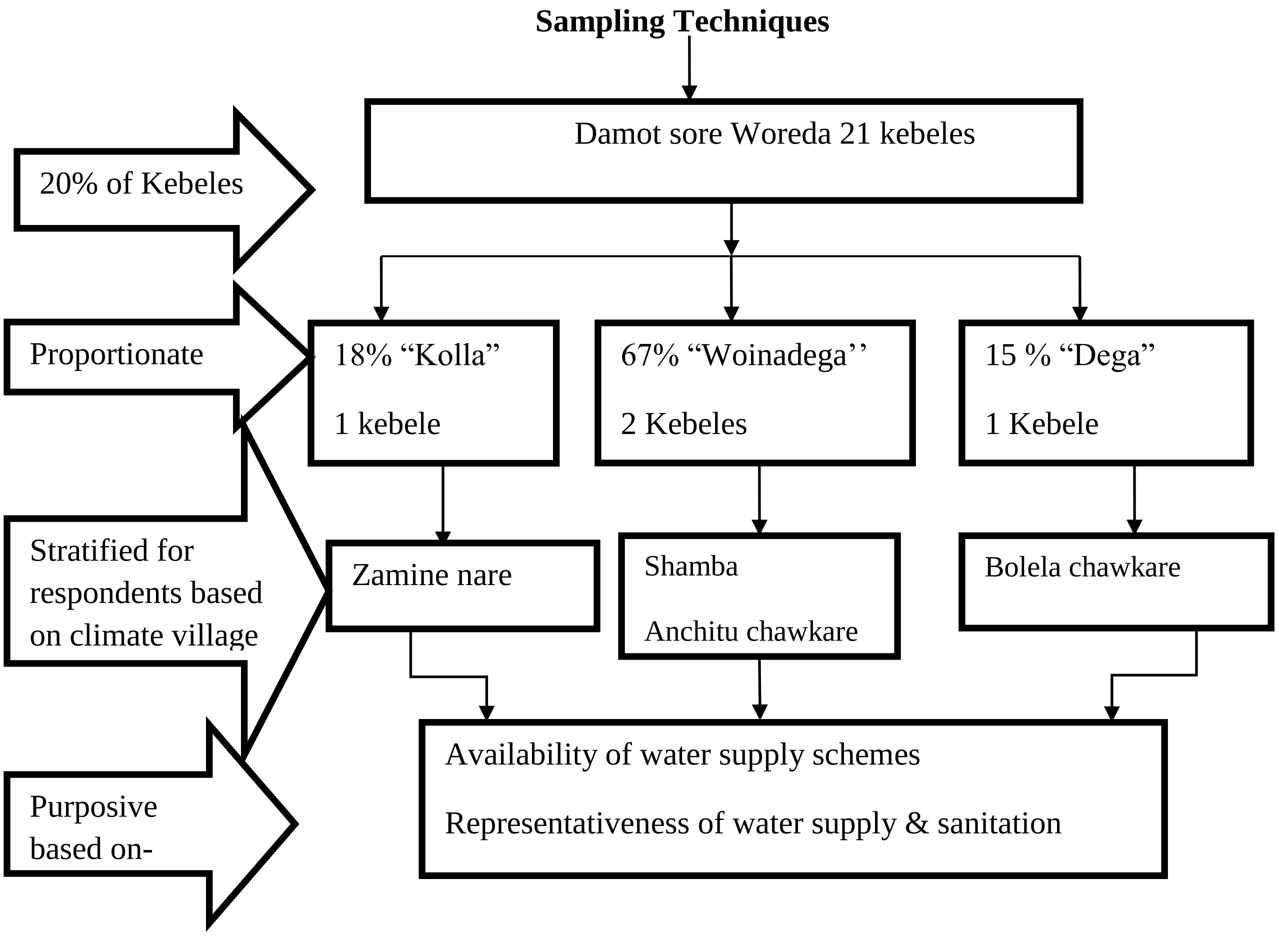

Figure 3-2 Schematic presentation of sampling design.

3.2.4. Sample size determination

Beneficiaries were the main primary data sources in this study. In order to ensure the generalization of the finding to larger population, the study considered adequate sample respondent for selection through appropriate techniques. The number of sample HHs for interview was determined by using the formula developed by Cochran (1977).

$$n' = \frac{Z^2pq}{d^2} \text{ ---------------- (3.1)} \qquad n = \frac{n'}{1+\frac{n'-1}{N}} \text{ --------------------- (3.2)}$$

Where, n' = desired sample size when the population > 10,000

n= No of samples size when the population < 10,000

Z= 95 % confidence level corresponding z-value is 1.96

P= 0.05 (proportion of the population to be included in the sample i.e. 5 %)

q= 1-0.05 i.e. (0.95), N= total number of HHs (3118) and

d= margin of error or degree of accuracy (0.05).

Since the populations (HHs) of the kebele involved in the study area are less than 10,000. Both equations (1 and 2) were used to determine the sample size required for this study as shown below: $n' = \frac{Z^2pq}{d^2}$ = $(1.96)^2$ x (0.05) x (0.95)/ $(0.05)^2$ = 73. Then,

$$n = \frac{n'}{1+\frac{n'-1}{N}} = 73/ (1+ (72)/ (3118) =72.$$

Accordingly, the sample size (n) of the study was 83 and the researcher considered 15% non-response rate for convenience sake. The total 83 households (HH) were selected from four Kebeles as sample populations developed by Cochran (1977) for primary data source were distributed to each Kebeles proportionally. Since all research methods have their own advantage and disadvantages, it is a common practice to try to reduce the disadvantages as much as possible by incorporating method of triangulation in order to fill the gaps of employed research methods.

Table 3-1 Total number of Sampled HHs for Target area

No	Kebeles	Village	Total HHs	Sampled HHs
1	Zaminenare	Shoke Giyaqomo	675	18
2	Shamba	Ashalicho Soripela Qeme	863	23
3	Anchitechawkare	Chawkare Dingama Borixancho	766	20
4	Bolelachawkare	Buzo Chawkare Demba	814	22
	Total		3118	83

3.3. Model specification to identify determinants of household water coverage

In this study, econometric model analysis were used to estimate relationship among demographic, economic, institutional and natural variables. Explanatory variables include selected socio-economic and biophysical factors that were assumed to influence water coverage of rural household in the study area. Changes in the dependent variables are explained by reference to changes in the explanatory variables. The available water consumption litre per capita per day of each sampled household was used as the dependent variable. The household water coverage determinants have done following the regression techniques in linear form. Because a linear regression model different from the logistic regression model is that the outcome variable in linear regression is continuous. Multiple regression analysis is more amenable, because it allows us to explicitly control for many other factors, which simultaneously affect the dependent variable. Furthermore, multiple regression models can accommodate many explanatory variables that may be correlated (Gujarati, 2004).

In the same reason multiple regression analysis has been applied by a number of other researchers in household water supply coverage studies such as Meseret (2012), Rashim and Sanatan (2013), Ashalew (2009) and Tarekegn (2014) among others.

3.3.1. Multiple linear regression analysis

Multiple Linear Regression (MLR) analysis is a statistical procedure that was used to examine more closely the relationship between a number of independent (explanatory) variables and the dependent (response) variable by fitting a linear (in the parameters) equation to observed data. The goal of MLR is to find an equation that can predict the dependent variable as a function of several independent variables (Coelho-Barros et al., 2008). The MLR equation, given n observations, given by:

$$y_{i=\beta o+\beta_1} x_{1i} + \beta_2 x_{2i} + \ldots + \beta_k x_{ki} + \in i \text{ ------------------------- (3.3)}$$

Where, y is the dependent variable (water consumption litres per person per day). x_1, x_2, …..x_k are the independent variables (time required to fetch water in minute, functionality of the water supply schemes, purpose of using potable water, habit of household water use, income level birr per month, education, point characterization, consumer satisfaction, distance to the scheme in meter and size of household in number). *i* index the n sample observations. β_0 is the y intercept (the value of y when all of the explanatory variables x_1, x_2..., x_k are equal to zero). β_1, β_2, …, β_k are the estimated multiple regression coefficients (each regression coefficient represents the change in the dependent variable relative to a unit change in the respective independent variable) and the term ε is a random error term (Gujarati, 2004). The existence of multicolinearity problems were checked before entering the selected variables in to the model in terms of variance inflation factor (VIF) for continuous and contingency coefficient for dummy and discrete variables, respectively. The reason for this is that the existence of multicolinearity affects seriously the parameters estimated.

3.3.2. Dependent variable for household water coverage

The dependent variable, water consumption litres per capita daily, were obtained by asking the total daily water consumption of the HH for different uses and dividing it by the number of people currently living in the family. HHs in rural area use bucket, clay jars (clay called 'Ensira' /'Madiga') or plastic jars 'Jerikan' to take water in to the house. It hypothesized to be a function of the following variables.

3.3.3. Independent variables for household water coverage

Time required for fetching water/waiting time:-It is the time it took/waiting time at the water source to fetch water. This implies that the more waiting time at the source and the longer one must queue, the less water from that source will be used (Gazzinelli et al., 1998). Thus hypothesized that the time for fetching water were negatively related to the quantity of water use.

Distance of water supply schemes:- Used to estimate how the water points/sources are spatially distributed in the Woreda. This means that those households located nearer to the water source are likely to use water more than others located farther away are. In a review conducted by Howard & Bartram (2003), it was revealed that distance is a crucial factor in determining access to water facilities. The further away the source of water is to a household, the less water consumed.

Household size:- The household size increase, the amount of water used per person per day significantly decrease. This implies that there was a negative relationship between household size and water consumption per capita (Aschalew, 2006).

Habit of household water use:- Household's water use perception and attitude about water supply schemes and quality treatment. Adequate protection of the water sources improves the quantity and quality of water from the sources.

Consumers' satisfaction:-Is the satisfaction of service takers using different indicators. Satisfaction with the quantity and quality of water namely; color of water, taste of water, smell, hardness of water, amount of water, time given for water service a day and general service of water points could be the main ones to mention.

Water point characterization:- is the character of water supply schemes namely either its micro schemes or macro schemes, catchment character of the scheme, source/points get prediction during dry and wet season.

Income:-The literature has shown a positive relation between wealth and water use. The wealthier families use more water per day. It assumed that poverty negatively affects water use because poor people cook less and often have less clothing to wash (Rashim and Sanatan, 2013).

Purpose of using potable water:-Water for multiple uses seems to depend on the capacity /quantity of water supply schemes. Some of the multiple uses are Drinking and cooking, washing clothes and bathing, animal watering and small irrigation.

Functionality of the schemes:-Technical preferences are likely to have effects on the sustainability of water facilities. Water source protection and maintenance taking into account both the operational status of water services and structural conditions as a whole. Together with construction of new drinking water and sanitation schemes to cover additional people deprived of the facilities, it requires maintaining functionality of the existing schemes for ensuring they serve the designed populations for the design period and possibly beyond.

Education: -It expected that, as the level of education increases among household members, the level of household awareness about the health benefits of water use (quantity and quality) also increases and water consumption per capita decrease (Rashim and Sanatan, 2013). Thus hypothesized that education level will affect negatively water consumption per capita.

3.4. Water quality assessment

3.4.1. Sample Size for water quality analysis

Temporal and spatial variation of water quality analysis is very important for the water sampling points to evaluate the water quality changes at one sampling point to the next sampling points and different season respectively. To analyze selected physico-chemical and bacteriological parameters eleven major functional water supply schemes were selected based on the public complaint on the water quality from four sampled kebeles. Then, the analyzed laboratory result were taken eleven samples from the source, eleven samples from storage(household containers) and eleven samples from point of-use(household drinking cups). Totally, thirty-three samples were taken to evaluate the average mean values for selected physicochemical and bacteriological parameters during dry season of January. For seasonal water quality analysis during the dry month of January eleven samples and wet month of April eleven samples were taken from the same water points. All the analyzed laboratory result compared with the Ethiopian standards and WHO guideline for drinking water quality and interpreted in accordance with the result obtained.

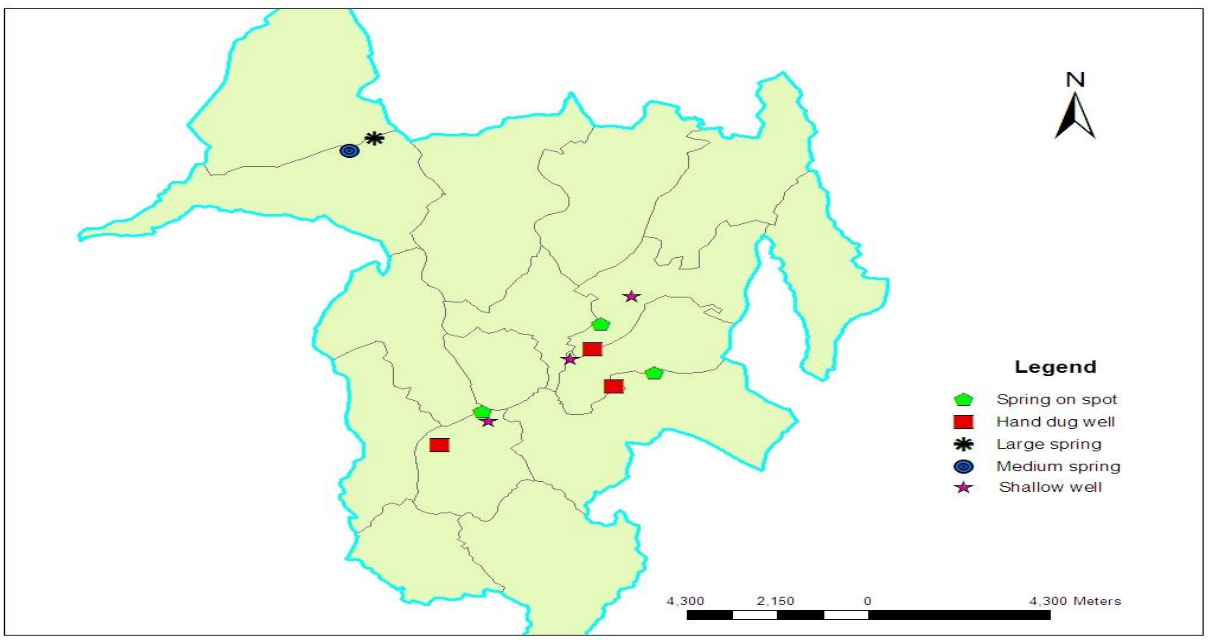

Figure 3-3 Water source/point mapping of the study area.

Table 3-2 Sampled water supply schemes for quality analysis

S. No	Sample kebele	Existing water supply schemes	Sampled Water supply schemes	Total water supply schemes
1	Zamine nare	1 on-spot spring	----------------	2
		1 large spring	1 large spring	
		1 medium spring	1 medium spring	
2	Shamba	1 on-spot spring	1 on-spot spring	3
		1 hand dug well	1 hand dug well	
		2 shallow well	1 shallow well	
3	Anchito chawkare	1 shallow well	1 shallow well	3
		1 hand dug well	1 hand dug well	
		2 on-spot spring	1 on-spot spring	
4	Bolela chawkare	2 on-spot spring	1 on-spot spring	3
		1 shallow well	1 shallow well	
		1 hand dug well	1 hand dug well	
	Total		11 water supply schemes were taken	

3.4.2. Water sampling procedure

Samples were collected in 1000ml polyethylene plastic bottles for different parameters from sampled water supply schemes. Water sampling and preservation techniques followed the standard methods of water sampling and preservation techniques (APHA, 1998; Hutton, 1996). Before collection, bottles were washed with concentrated nitric acid and distilled water to avoid contamination. The water samples were handled aseptically in sterile glass bottles, labeled and kept in an ice-box during transportation to the laboratory of school of Bio-system and Environmental Engineering Hawassa university for physico-chemical quality analysis and Wolaita Zone Water, Mine, Energy and Irrigation office for bacteriological quality analysis. Bottles were preserved using icebox and a water samples from sampled sites of the study area were taken and studied for the selected physicochemical and bacteriological parameters. The water samples analyzed for both physicochemical and bacteriological parameters are listed in table 3.3.

Table 3-3 Major physicochemical and bacteriological parameters for the sampled water

S. No	Physico-chemical parameters	Bacteriological parameters
1	Temperature	1. E.coli/Thermo tolerant coliform bacteria
2	pH	
3	Electrical conductivity	
4	Turbidity	
5	Total hardness	
6	Nitrate	
7	Chloride	
8	Fluoride	
9	Iron	
10	Phosphate	
11	Total dissolved solids	
12	Magnesium	

3.5. Method of water quality analysis and instruments

3.5.1. Analysis of physico-chemical parameters

In-situ measurements were used to determine sensitive water quality parameters, which include; temperature, pH, turbidity, EC and TDS. Temperature and pH was analyzed by using thermometer and portable digital pH meter (pH meter ELE international), respectively. The pH meter were calibrated just before analysis using pH 4.0 and pH 7.0 and it was rinsed with distilled water from one sample to the other following the pH meter operation manual. With regard to turbidity, it was analyzed using portable Wagtech International turbidity meter (Weg-WT 3020 Wagtech international), whereas electrical conductivity and total dissolved solids (TDS) were analyzed using portable digital conductivity meter. Their measurements were taken immediately after the samples were collected on each site.

Magnesium, total hardness, chloride and Fluoride was determined by photometric measurements using paqualab photometer by adjusting the wavelength (580 μm) and keeping their reaction periods and analytical reagents analyzed by using their respective standards. Iron was determined by using paqualab photometer by 520μm of the wavelength. The nutrients like nitrate and phosphate were measured by photometric measurements using paqualab photometer by adjusting the wavelength(560 μm), keeping their reaction periods and analytical reagents were analyzed by following standard methods (APHA, 1998) and using a standard laboratory setup. All chemicals and reagents that were used for this analysis were analytical grade. Equipment cleaned and sterilized thoroughly before each use to avoid secondary contamination and ensure accurate results.

3.5.2. Analysis of bacteriological parameters

With regard to bacteriological parameters, samples were analyzed using membrane filtration method for water quality to determine the degree of contamination (WHO, 2008; APHA, 1998). All samples were analyzed for the presence of total coliforms (TC). The procedures include membrane filtration followed by incubation of the membranes on selective media. Composite samples were used to improve the precision of the estimated average contaminant concentrations. In the laboratory, the three samples from each site were mixed into one and a composite sample was subjected for membrane filter analysis of total coliform.

The composite samples were mixed thoroughly by shaking and filtered under laboratory hood, using WagTech membrane filtration apparatus and membranes, pore size 0.45μm, 47mm diameter, sterile and gridded. It was shaking properly to get red color. The membranes then transferred aseptically to m-FC agar with rosolic acid in glass Petri dishes. Prepared culture dishes were inverted and the incubator was calibrated at 37^{o}C. Upon completion of the incubation period (24 hour) typical Yellow Colonies were seen, which are characteristic of total coliform on the surface of membrane filter then counted using a low power binocular wide field-dissecting microscope, with a cool white fluorescent light source for optimal viewing sheen.

3.6. Assessment of sanitation condition of the Woreda

In order to assess the sanitation condition of the study area, an interview was conducted with structured questionnaire. Accordingly, data related to sanitation and hygienic condition like toilet availability, its type, habit of using toilet, hand washing facility and disposal of waste were collected from the households. The questionnaire was supported by household survey, key informant interview and personal observation. Statistical correlation was employed and significant positive correlations were seen between sanitation and hygiene determining factors.

3.7. Data analysis

After gathering the data, relevant statistical methods of analysis were used in order to come up with the appropriate result. The results are presented in both quantitative and qualitative terms. The SPSS version 20 and statistical tools like arithmetic mean, minimum, maximum, standard deviation, percentages, tables, maps, bar graphs and explanation building descriptive and statistical methods were used to analyze findings. After computing the descriptive statistics, multiple linear regression models were employed to identify the statistically significant water coverage determinant variables in the study area and associations of the variables respectively. Results of water quality analysis from the source, storage containers, point of-use(consumption) and dry and wet season variation were compared against standards set by Ethiopian standards (2002) and WHO (2008). Moreover, ANOVA was used to determine the significant differences in the mean values of the water quality parameters at the various sampled sites at $p < 0.05$ significant level and also correlation was employed to see statistical significance relation between physico-chemical and bacteriological parameters and sanitation and hygiene influencing factors. Deduction made from these measures and compared with the existing literature to arrive at the conclusion of the study.

3.8. Ethical consideration

Before conducting the data collection activity, the researcher was informed the research purpose and convince the concerned bodies. Thus, collection of data was undertaken after obtaining permission from the concerned offices. With regard to data collection at the household level, study objectives was clearly explained to the household. Each household has been told that the information provided would be confidential and used only for the research purpose.

4. RESULTS AND DISCUSSION

4.1. Household water use and collection

Domestic water use patterns are generally similar in the study area regardless of the type of the water supply schemes and the distances covered to reach it. The main uses of water in the households in the study area are drinking, cooking, and washing clothes and other activities like watering animals among others. All respondent households were using the water supply for drinking and cooking, 71 % for washing, 66% for livestock and 11% for small irrigation. While the fundamental priority of water use from the improved water sources is for human consumption. At many of the protected springs, the taps are used not only for domestic water needs but also for animal watering and small irrigation. These findings agreed with previous research in Tehuledere Woreda, northeast Ethiopia by Seid et al (2013) and in WA, Ghana by Joseph (2013).

Table 4-1 Different purposes for which respondents use water

S. No	Purpose of using water	Frequency	Percentage
1	Drinking and cooking	83	100
2	Washing clothes and bathing	59	71
3	Animal watering /livestock	55	66
4	Small irrigation/ for vegetable production	9	11

Households' reported that the individuals who were responsible for fetching water, mostly women, travel on average two times in a day to the water sources/points on normal condition. The average household water use in Bolelachawkare is 25 litres/day, Anchitochawkare is 37.5 litres/day, Shamba is 30.5 litres/day and Zaminenare is 18 litres/day. The maximum amount of household's water use in study area is 70 liters/day, the average water use in study area is 27.75 litres/day and the standard deviation was 13.3 litres/day. However, this varied per household depending on the household size, the distance to the water point and the waiting time at the water sources/points. This finding was much lower than previously reported research in Tehuledere

Woreda, northeast Ethiopia, (i.e., about 29 and 25 litres per capita in the rainy and dry seasons, respectively (Seid et al., 2013).

Table 4-2 The average water consumption of respondents in litres per household per day.

S. No	Statistical parameters	Bolelachawkare n= 22	Anchitochawkare n= 20	Shamba n= 23	Zaminenare n= 18	Total N=83
1	Minimum	15	20	20	10	16.25
2	Maximum	80	100	60	40	70
3	Average	25	37.5	30.5	18	27.75
4	Standard deviation	12.5	16	11.6	13	13.3

4.1.1. Time required for fetching water

The respondents in the study area was asked to give information on the time it took them to fetch water from water supply schemes. Although the values obtained were not based on accurate measurement it is roughly used to estimate the time taken from rural water supply services. The researcher was so careful about overestimation and underestimation. The minimum and maximum time to fetch water from the supplied services including waiting time varies from 15 to 30 minutes and 75 to 120 minutes, respectively, with a mean duration varies from 41 to 64 minutes and standard deviation of 19.85 minutes. The mean duration to fetch water from the supplied services includes the time required for round trip from beneficiaries and waiting time at the water supply schemes. The standard deviation indicates there is great difference among the households for water fetching time. The time taken to fetch water from protected facilities in this study exceeded the guide line value recommended by WHO(2008), which is set at 15 minutes of walking distance, equivalent to a distance of about one kilometer.

Table 4-3 The average time to fetch drinking water

S. No	Statistical parameters	Time taken in minutes to fetch water				
		Bolelachawkare n= 22	Anchitochawkare n= 20	Shamba n= 23	Zaminenare n= 18	Total N=83
1	Minimum for the scheme	15	15	20	30	20
2	Maximum for the scheme	95	105	75	120	98.75
3	Average for the scheme	45.5	60.5	41	64	52.75
4	Standard deviation	17.4	14	21	27	19.85

4.1.2. Distance/Spatial distribution of water points in the Woreda

The mean duration from home to the source of water for round trip is (average 52.75 minutes) above the recommended value of WHO. The coverage of water sources/points within 1.5km is only 10,567.15ha, out of the total area of the Woreda, which is 18,091.34ha; hence, the coverage of overall Woreda including the non-functional water sources/ points was only 58.4%. This was used to estimate how the water points or sources are spatially distributed in the Woreda.

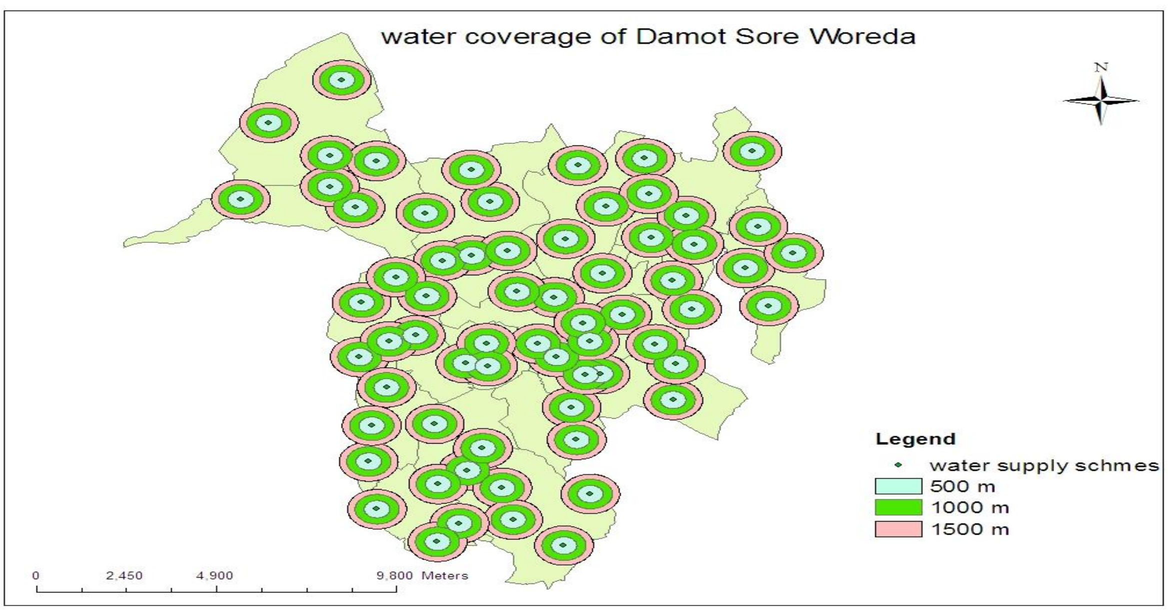

Figure 4-1 Spatial distribution of water points and their status in the Woreda in terms of distance.

4.1.3. Water consumption (litre per capita per day)

All the households use ''jerrycans'' to collect water; these jerrycans typically hold 20 litres. Children also use smaller jerrycans, up to 10 litres. The respondents were asked to tell the average number of litres in terms of "jerrycan" that their family used per day due to unfamiliarity of measuring in litres besides their inability to tell the amount in liters. The consumption per capita of water in a respondent's household were then calculated by multiplying the number of "jerrycan" used per day with the amount of litres it contains and then dividing the result by the household's family size. According to table 4.4, the average volume of water used by litres per person per day ranged from 1 to 18 litres and the average water consumption per capita ranges from 5 to 9 litres and less used by the majority. This was significantly different from WHO guideline value set at least 20 litres per capita per day (WHO, 2008 and Webster et al., 1999). Inadequate drinking water adversely affects personal hygiene, clean food preparation and housing sanitation, hence favoring the transmission of water borne and water washed communicable diseases. Almost 100% of residents consume less than 20 litres of water in a day, as indicated in the table 4.4. The standard deviation was found to be 2.95 litres implying there is great variation in the pattern of water consumption per person per day among different households in the study area. Highest average values were recorded in Anchitochawkare and the lowest average value was recorded in Zaminenare kebele. According to Wallingford (2003), a minimum quantity of 25 l/capita/day domestic water supply is categorized as basic level of service. With regard to this value, the current average domestic water consumption of Damot Sore Woreda not satisfies basic level of service to the people.

Table 4-4 Water consumption in litres per capita per day.

S. No	Statistical parameters	Amount in litres per person per day(in l/c/d)				
		Bolelachawkare n= 22	Anchitochawkare n= 20	Shamba n= 23	Zaminenare n= 18	Total N= 83
1	Minimum volume	1.5	2.8	1.8	1	1.8
2	Maximum volume	11	18	15	10	13.5
3	Average volume	6.5	9	7.3	5	6.95
4	Standard variation	2.5	3.5	2.8	3	2.95

4.1.4. Habit of household water use

Water treatment is essential to improving water quality, which reduces risks of water borne diseases (WHO, 2003). According to the consumers' responses 32(38.5%) collect water which is in contact with their hands and majority of them 44(53%) have no separate water containers in their home to store it from the water used for other purposes. Most of them 59(71%) did not use any particular treatment at home before use. Although some people use water treatment in their home, general water treatment for all household basic needs is still limited in study area. Poor sanitation and poor hygiene were the main effects of the contaminated water during transportation and after storage in household. This finding was in agreement to the studies conducted elsewhere in Ethiopia (Dagnew et al., 2007 and Mengesha et al., 2004). The results of sanitation and hygiene practices of the consumers at the households are shown in Table 4.5.

Table 4-5 Sanitation and hygiene practice of consumers.

S. No	Questions reflected to the consumers	Yes		No	
		Frequency	%	Frequency	%
1	Separate container for storage of drinking water	39	46.9	44	53
2	Have no contact with your hand	51	61.4	32	38.5
3	Particular treatment for your drinking water	24	28.9	59	71

4.1.5. Water supply system and consumer's satisfaction

It is a known fact that the water period is available to the customers in a day is an indicator of reliability of the water supply system, which in turn has a significant bearing on consumer attitudes. Consumer satisfaction can accessed from service takers in different ways using different indicators. Satisfaction with the quality of water namely: color of water, taste of water, smell, hardness of water, amount of the water, time given for water service a day, general services of water points, whether they stand in line for long period of time to collect water could be the main one's to mention.

As UNDP (2005) noted control of water variability is important because poverty stricken and vulnerable households can have devastating effects in case of water related events like droughts and floods. With this regard, the survey found that only 24(28%) of respondents are satisfied with the provided amount of water, 57(68%) are satisfied with the quality of water namely taste, color, smell and hardness of water. This community satisfaction is a tool for the overall water supply services and projects. When the respondents were asked to tell the period through which the quantity of water supplied was not adequate to fulfill their demand, they specified the period i.e. during mid-day (4-10 o'clock) through which low quantity of water was obtained and 26(32%) of them complained the inconvenience of the water quality. The former problems most pronounced in three kebeles of the study area namely Bolelachawkare, Shamba and Zaminenare kebeles. A study carried out by Gulyani et al (2005) indicated that service availability, apart from easy access, strongly influences household water satisfaction. However, in the study area, water is available for limited time intervals. As a result, consumers were not satisfied with the duration of water availability in a day.

4.1.6. Water points characterization, their current status and coverage

There are two types of rural water supply schemes in the study area. The micro schemes are defined as those rural water schemes comprising point source supplies such as hand dug well equipped with hand-pumps, collection tanks, stand posts and protected springs whilst macro schemes are those schemes such as, gravity schemes or point sources with collection tanks supplying more than four communal standpipes (GOS, 2003). Springs, shallow wells and hand-dug wells were the main source of water for household used in the study area where the schemes are functional. When the protected springs, hand dug wells and shallow wells were not functional: unprotected springs and rivers were mentioned as alternative sources of water used by the respondents, as 7(9.4%) of the respondents in the study area were using rivers. This is the main problem in kebeles where the sources/water points were not functional or when the sources/ points get unpredictable in dry (Jan–March) time. The working hours of the sources/water points fall during this period and ease of use of water is erratic. These kebeles confront water scarcity due to non-functionality or abnormality of existing water supply schemes especially in Zaminenare and Shamba kebeles. The normal maintenance period for a water facility as recommended by MoWR (2007) is 2 to 3 days. The long maintenance period observed to be in excess of 4 months during the study period might contribute to the non-reliability of water services in the study area. Observation and field visit result showed that most of the water points are not neat at all as demonstrated by poor drainage and water stagnation, bad smell and in some of the sources by the presence of livestock waste. Some of them have functional guards. Catchments rehabilitation with the aim of increasing ground water recharge was done around the surroundings of only 3(27%) of the water points and 6(55%) have animal troughs. An illustration of sampled water points in the study area are shown in the following figures.


Zaminenare kebele medium spring


Anchitochawkare kebele shallow well


Shamba kebele hand dug well


Bolelachawkare kebele on-spot spring

Figure 4-2 Some of existing water supply schemes in the study area (January, 2017).

As far as water supply services are concerned, some development activities has been done by Zonal, Woreda water resources office and NGOs to alleviate the problem of potable water in the Woreda. However, the problem of potable water supply is still very sounding in the Woreda. In addition to this the existing water supply schemes are characterized by very low service coverage, limited service over the day from public distribution points, poor operation and maintenance as specified by key personnel and site observation. In relation to this, the following adverse conditions were identified as problems related to operation and maintenance functions of Woreda Water Resource Development Office; lack of awareness of beneficiaries, lack of spare parts, design problem, poor financial management, inadequate planning, lack of preventive maintenance and lack of trained personnel who fully understand how to operate the systems and low capacity of the schemes to satisfy the demand are the main ones. As per the official data of Woreda Water Resource Office, 4 hand dug well, 11 shallow well, 13 on-spot spring, 2 bore hole and 4 other water supply schemes are non-functional. Hence, in the Woreda 65% of the water sources/points are functional, 32% of them are not and 3% of them were abandoned. The Ministry of Water Resources estimates that 33% of water supply schemes in Ethiopia are non-functional at any time, with negative impacts on coverage and universal access due to lack of funds for operation and maintenance, inadequate community mobilization and commitment and a lack of spare parts (MoWR, 2007 and Moriarty et al., 2009). From existing water supply schemes in the Woreda, 7 hand dug wells are estimated to serve 4575 people, 25 on-spot springs are estimated to serve 18,407 people, 15 shallow wells are estimated to serve 24,500, 1 borehole estimated to serve 5100 and 6 other schemes are estimated to serve 1820 people. Since the population served by the schemes in the Woreda are 54,402 out of the total population of 116,847 hence; the total coverage is 46.5%. The remaining 53.5% not covered with the reasonable population load per a single water source/point. This showed that, the water supply coverage of Damot Sore Woreda is low.

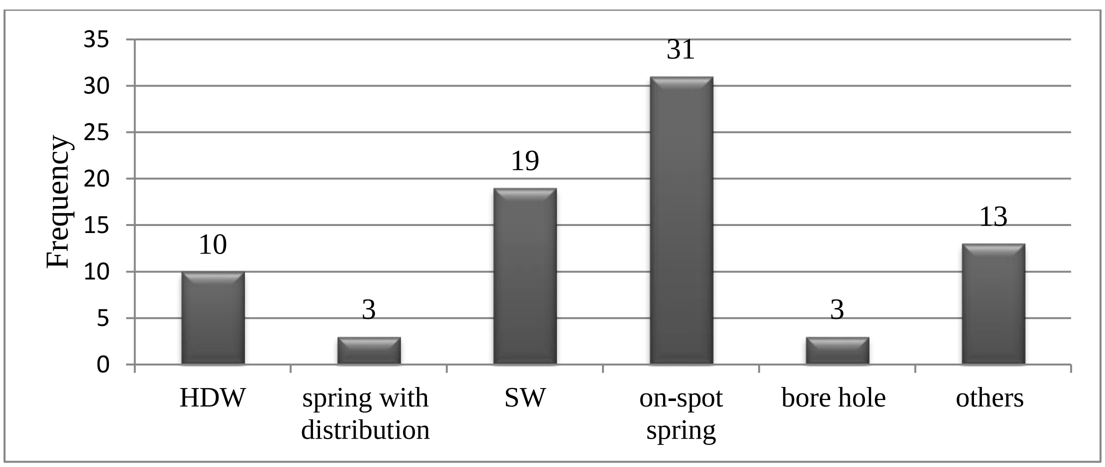

Figure 4-3 Schematic representations of types of schemes in the Woreda and their status.

4.2. Factor analysis

Attempts were made to identify factors responsible for the determinations of rural household water coverage among the sampled households. Occurrence of strong multicolinearity problems was checked for the continuous explanatory variables prior to estimation of the model using VIF and contingency coefficient. The result showed there was no strong multicolinearity problems among the explanatory variables included in the model (Appendix 4).

The MLR model result showed that the coefficient of determination i.e. the adjusted R-values was 0.991. This implies that about 99.1% of the variation in the dependent variable is explained by the variation of the independent variables, indicating relatively high explanatory power of the model (Appendix 2). The econometric results were almost indicating that the homoscedasticity assumption was not violated (Appendix 4). Appendix 5 indicates that the model has no omitted variables. As the result signified, the chi-square distribution is suggesting that the linear regression model as the basis of analysis which means that the model is correctly specified (Appendix 2).

4.2.1. Determinants of household water coverage in the study area

The result indicated that, out of the 10 hypothesized variables which were included in the multiple linear regression models four variables were found to be statistically significant to influence the household water coverage (Appendix 4). These are functionality of water supply schemes, distance to the schemes, time required to fetch water and size of the household (Table 4.6).

Family size:- Family size was statistically significant at 1% probability level and had a negative coefficient of 0.813, which implies that for every increase in an individual in a household, water coverage decreases by 0.813 water consumption litres per capita (Table 4.6). Larger family size has a negative impact on household water availability. That means when the size of family members increase the household was less likely to be water coverage. A study by Ashalew (2009) also found a strong negative relationship between family size and household water coverage respect to water consumption litres per capita. Another study by Meseret (2012) said, for every one-unit increase in the household size there is a decrease in the water consumption per capita by 1.9 times in urban and 1.7 times in rural areas.

Functionality of the schemes:- The study result showed that functionality of the schemes is positively related with water coverage and statistically significant at 5% probability level. The coefficient of the variable implies that increasing the number of function of the schemes, increases water coverage availability of the households by a factor of 0.295 (Table 4.6). Aschalew (2009) pointed out that one of the daunting challenges in the water supply sector is securing resources to manage and maintain frequently breaking water facilities and keeping the water sources operating in a sustainable manner, which determines rural water supply systems.

Time required for fetching water/waiting time:- Time was statistically significant at 1% probability level and had a negative coefficient of 0.255, which implies that for every increase of time in minute for a household, water coverage decreases by 0.255 water consumption litre per capita per day (Table 4.6). More water fetching time has a negative impact on household water availability. That means when the time required to fetch water increase the household was less likely to be water coverage. A study by Aschalew (2009) also found a strong negative relationship between fetching time and household water consumption per liter. The waiting time at the sources varies from 0 to 120 minutes, with a mean duration of 25 minutes and standard deviation of 23 minutes.

Distance to the schemes:- Distance was statistically significant at 5 % probability level and had a negative coefficient of 0.001, which implies that for every increase of distance in meter for a household, water coverage decreases by 0.001 litre per capita per day(Table 4.6). Larger distance to the water supply schemes has a negative impact on household water availability. That means when the distance required reaching water points the household was less likely to be water coverage. A study by Ashalew (2009) clearly observed that the per capita water use is negatively and significantly determined by the distance of water source from household (i.e., keeping other factors constant, as the distance of a water source from the household increases by a kilometer, the per capita water use significantly decreases by 6.2 liters).

Table 4-6 Determinants of household water coverage model result

Variables	Coefficient	Std. Err	T	P
Education	-.055	.104	-.524	.602
Income level (birr/ month)	.211	.392	.538	.129
Functionality of the water supply scheme	.295	.117	2.519	.014**
Consumer satisfaction	.260	.201	1.292	.200
Purpose of using potable water	-.193	.170	-1.131	.262
Distance to the scheme in meter	-.001	.0003	-2.651	.010**
Point characterization	.046	.180	.257	.798
Habit of household water use	.074	.160	.464	.644
Size of household in number	-.813	.085	-9.543	.000*
Time to fetch in minute	-.255	.026	-9.768	.000*

* Significant at less than 1% probability and** significant at less than 5 % probability.

4.3. Water quality at the source, storage and point of use

4.3.1. Physico-chemical analysis for the source, storage and point of use

Water quality criteria, standards and the related legislation are used to interpret water quality characterization. The most common national requirements are suitability of water quality for drinking and domestic purpose. Many countries base their own standards on the standards of world health organization (WHO) guidelines for drinking water quality (WHO, 2004).

The World Health Organization (WHO), drinking water quality guidelines provide international norms on water quality and human health be used as the basis for regulation and standard setting in developing and developed countries worldwide. These guidelines adopted by many countries as national guidelines to follow. These countries including Ethiopia set drinking water quality guidelines based on the WHO guidelines but may modify these based on what is achievable in the country. The analyzed laboratory result were taken eleven samples from the source, eleven samples from storage(household containers) and eleven samples from point of-use(drinking cup). Totally, thirty-three samples were taken to evaluate the average mean values for selected physico-chemical and bacteriological parameters during dry season of January, then compared with the Ethiopia and WHO drinking water quality standards and interpreted in accordance with the result obtained.

Table 4-7 Mean value of physico-chemical parameters for the source, storage and point of-use.

Parameters	Units	Source		Storage		Point of-use		Standards	
		Mean	Std	Mean	Std	Mean	Std	ES	WHO
Temp.	^oC	23.27	1.737	21.63	1.566	21.63	1.567	--	<15
EC	µs/cm	100.8	25.54	81.7	20.93	81.7	20.93	1500	1000
Ph	Ph	7.22	0.93	7.04	0.835	7.04	0.835	6.5-8.5	6.5-8.5
Turbidity	NTU	12.18	17.75	10.74	15.85	10.74	15.75	7	5
TDS	Mg/l	67.39	17.19	54.69	14.15	54.69	14.15	1000	1000
TH as $CaCO_3$	Mg/l	49.63	28.786	39.36	25.6	39.36	25.6	300	300
Nitrate	Mg/l	1.91	0.875	1.53	.58	1.53	0.58	50	50
Chloride	Mg/l	7.64	1.14	7.29	1.02	7.29	1.02	250	250
Fluoride	Mg/l	0.63	0.28	0.59	0.28	0.58	0.28	3	1.5
Iron	Mg/l	0.07	0.06	0.06	0.06	0.06	0.06	0.4	0.3
Magnesium	Mg/l	10.89	1.61	8.9	1.27	8.9	1.27	50	50
Phosphate	Mg/l	0.44	0.18	0.4	0.18	0.4	0.18	0.02	0.005

Temperature

It was one of the physical parameters used to evaluate quality of drinking water. The mean values of temperature for the source, storage and point of-use were 23.27±1.7^oC, 21.63±1.56 ^oC and 21.63±1.56 ^oC, respectively. Minimum is 22^oC from the source of Bolelachawkare kebele hand dug well and maximum is 27^oC from the source of Zaminenare kebele large spring (Appendix 8 and 9). After storage, it has varied between 21 ^oC and 25 ^oC (Appendix 8 and 9).

A slightly higher temperature of 25.5^0C reported from water source samples than the storage from Nigeria (Agbogu et al., 2006). There was a variation in the mean values of water temperature in most of sampled sites from the source to storage as they have different atmospheric temperature. As a result, the differences in the mean temperature for the source to storage sampled sites were significant at $p< 0.05$ significant level with $p=0.036$ (Appendix 11). Although the mean temperature values of the study area were beyond the recommended limit of WHO guideline.

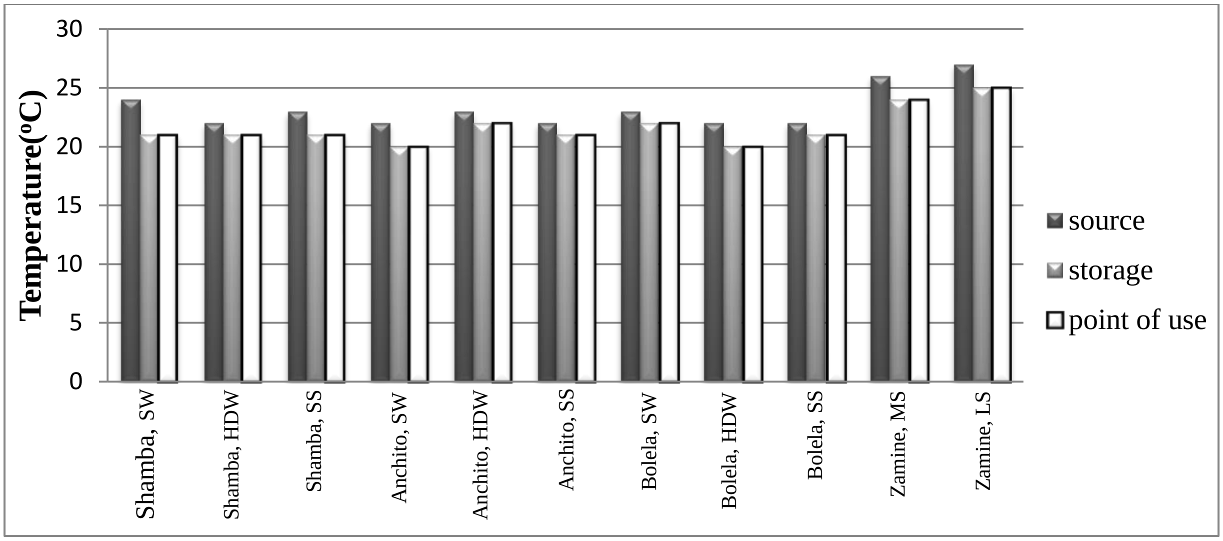

Figure 4-4 The value of temperature at the source, storage and point of-use

pH and Turbidity

The result of laboratory analysis revealed that the mean values of pH for the source, storage and point of-use were 7.22±0.93pH, 7.04±0.83pH and 7.04±0.83pH, respectively. This finding agreed to the ES and WHO standards, except Shamba kebele hand dug well which is slightly acidic (5.8pH). Among the thirty three sampled points the maximum pH value 8.5 was recorded in a water sample collected from a hand dug well of Bolelachawkare kebele at the source whereas the minimum pH 5.8 was recorded in water sample collected from hand dug well of Shamba kebele(Appendix 6 and 8). After storage, it has varied between 5.6 and 8.4pH (Appendix 6 and 8). The study showed that a decrease of the pH value in stored water samples. Normally, the variation in pH is due to nitrates, carbon dioxide or dissolved minerals that normally affect the pH and may related to the bacterial development and activity. This finding agreed with previous research by Achadu et al (2013). However, the differences in the mean pH of the source, storage and point of use sampled sites were not significant at $p < 0.05$ significant level (Appendix 11).

Turbidity in drinking water is due to by particulate matter that present from water source of inadequate filtration. These particulates can protect microorganisms from the effects of disinfection and can stimulate bacterial growth (Hunter et al., 2009). Mean value of turbidity for source to storage were 12.18±17.75NTU to 10.74±15.75NTU, respectively. At the source, high turbidity value was observed as the particulate matter floats on the surface of the source. But, in the household water storage container, the particulate matter settles down resulting in low turbidity value. Nine samples had their turbidity value above the acceptable value; hand dug well (source, storage and point of use) at Bolelachawkare, on-spot spring (source, storage and point of use) at Anchitochawkare and hand dug well (source, storage and point of use) at Shamba kebele (Appendix 6, 7 and 8). However, the differences in the mean turbidity of the source, storage and point of use sampled sites were not significant at $p<0.05$ significant level (Appendix 11). The correlation result for the association between turbidity and TH revealed that there was a positive relationship between them with the correlation value of 0.534 (Appendix 13). Some forms of primary treatment like coagulation and flocculation, therefore needed to be carried out on this water sources before any disinfection treatment can be done, otherwise, high turbidity values will shield the pathogenic organisms from chemicals and render the treatment ineffective (Hunter et al., 2009).

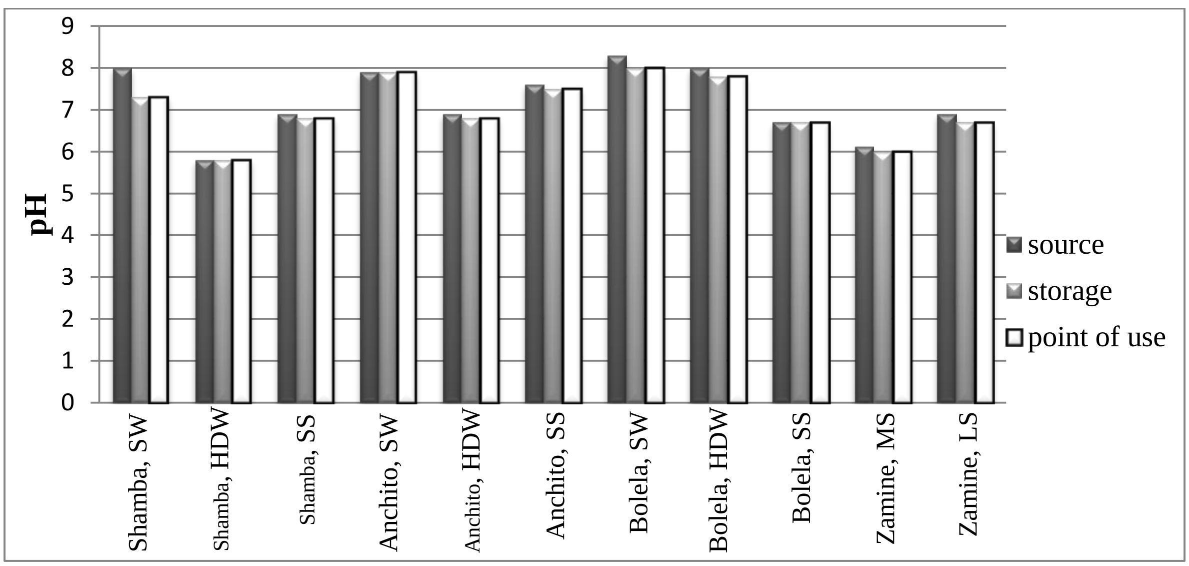

Figure 4-5 The value of pH at the source, storage and point of-use.

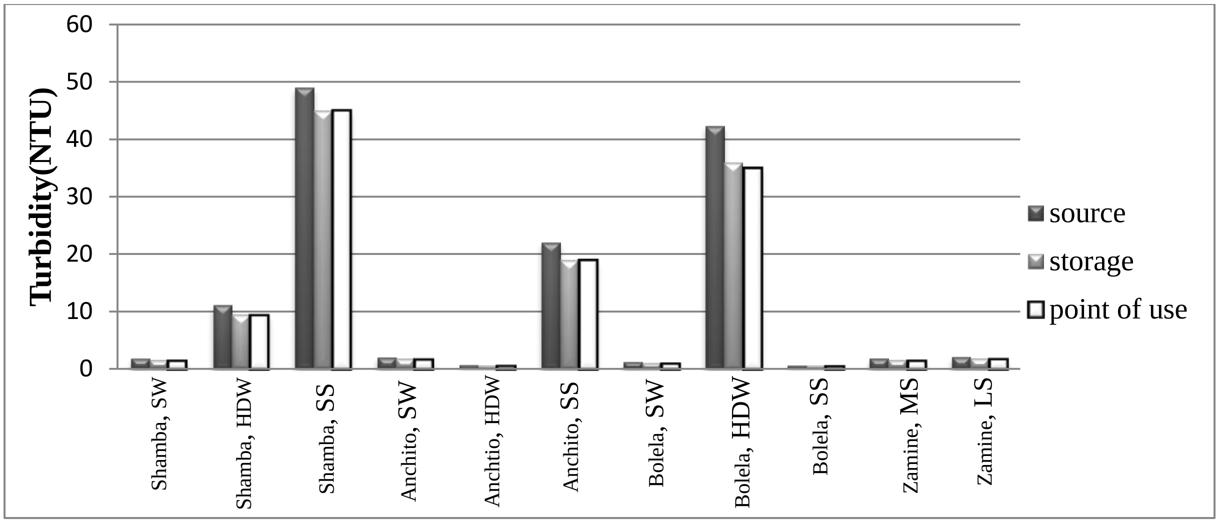

Figure 4-6 The value of Turbidity at the source, storage and point of-use.

Electrical conductivity (EC) and Total dissolved solids (TDS)

Conductivity is a measure of the ability of water to pass an electrical current and affected by the presence of dissolved solids. Mean value of EC for source, storage and point of-use were 100.8±25.5μs/cm, 81.7±20.9μs/cm and 81.7±20.9μs/cm, respectively. In thirty-three sampled points, EC minimum value was 60.5μs/cm from on-spot spring and maximum value was 137.9μs/cm from shallow well at Shamba kebele (Appendix 6). After storage, it has varied between 50μs/cm and 121μs/cm (Appendix 6). In fact, the laboratory results showed that decrease of the electrical conductivity level in stored water samples. This is due to conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) and magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Also, when water temperature increases, so will conductivity. For every 1°C increase, conductivity values can increase 2-4% and the reverse is also true (Barron and Ashton, 2005). However, the differences in the mean EC of the source, storage and point of use sampled sites were not significant at $p < 0.05$ significant level (Appendix 11). The correlation result for the association between temperature and electrical conductivity revealed that there was a positive relationship between them with the correlation value of 0.372 (Appendix 13). The analyzed value is in far below the ES and WHO guideline value prescribed for drinking purpose. The EC value was rated under excellent classes for all human, livestock and poultry watering purposes (WHO, 2008), i.e., <1000 μS/cm.

Total dissolved solids values <1000 considered fresh water and values >1000 mg/l considered brackish water (Dagnew et al., 2007). Mean value of TDS for source, storage and point of-use were 67.39±17.19mg/l, 54.69±14.15mg/l and 54.69±14.15mg/l, respectively. From the result of analyzed samples the value of TDS was found within the acceptable range of WHO and also according to this studied result it is possible to consider the Woreda water supply as fresh water with respect to TDS concentration. The minimum and maximum TDS value obtained on the site were 40.5mg/L to 92.3mg/L at Shamba kebele, respectively (Appendix 6). After storage, it has varied between 33.5mg/l and 81mg/l (Appendix 6). The concentrations of TDS decrease from source to storage. However, the differences in the mean TDS of the source, storage and point of-use sampled sites were not significant at $p<0.05$ significant level (Appendix 11).

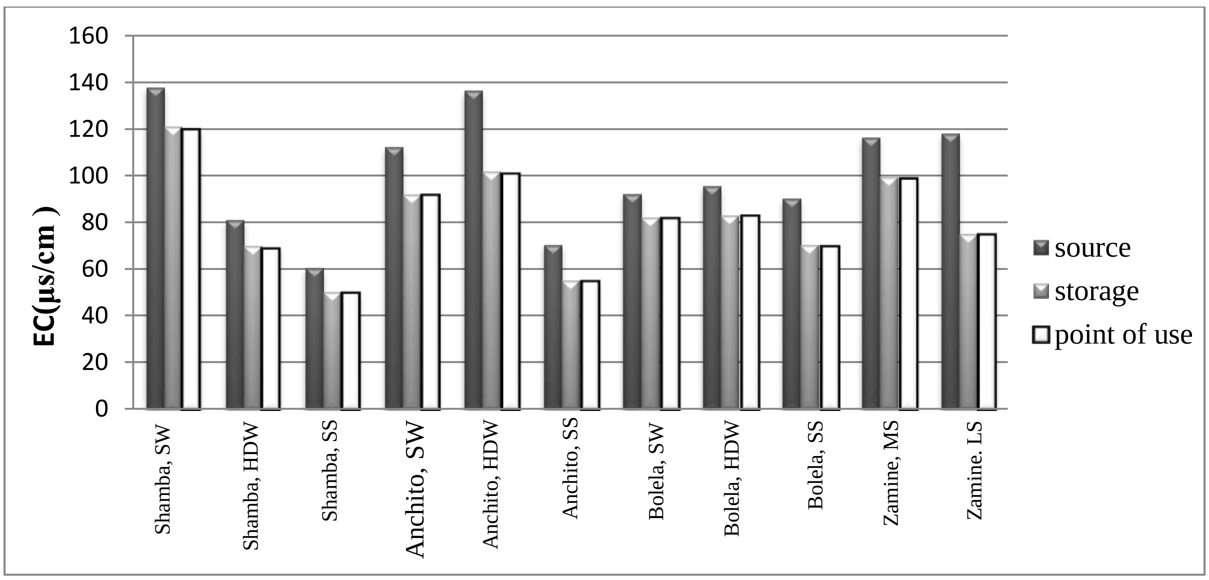

Figure 4-7 The value of EC at the source, storage and point of-use.

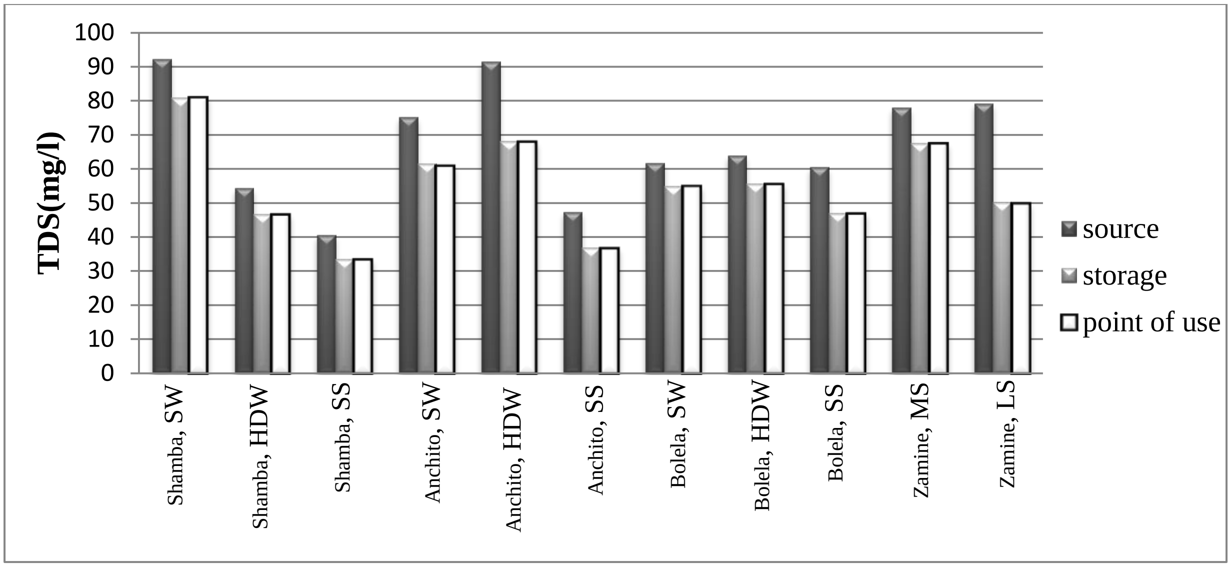

Figure 4-8 The value of TDS at the source, storage and point of-use.

Total Hardness

The result of laboratory analysis revealed that the mean value of TH for the source, storage and point of-use were 49.63± 28.65mg/l, 39.36± 25.6mg/l and 39.36± 25.6mg/l, respectively. The minimum and maximum hardness value recorded were 22mg/l from medium spring at Zaminenare and 102mg/l from on-spot spring at Bolelachawkare Kebeles, respectively (Appendix 8 and 9). After storage, it has varied between 18 and 85mg/l (Appendix 8 and 9). Total hardness level showed that there is variation from source to storage. The source has high value of total hardness due to high quantity of magnesium or calcium ions on the source than storage and point of-use value. However, the differences in the mean TH of the source, storage and point of use sampled sites were not significant at $p<0.05$ significant level (Appendix 11). This finding agreed with previous research by Douhri et al (2015), i.e. the total Hardness at source varied between 8.17 and 70.31 (mg/l) and between 8.06 and 60.90 (mg/l) after storage. The entire analyzed sample has their total hardness values far less than the recommended limit of both Ethiopian and WHO standards.

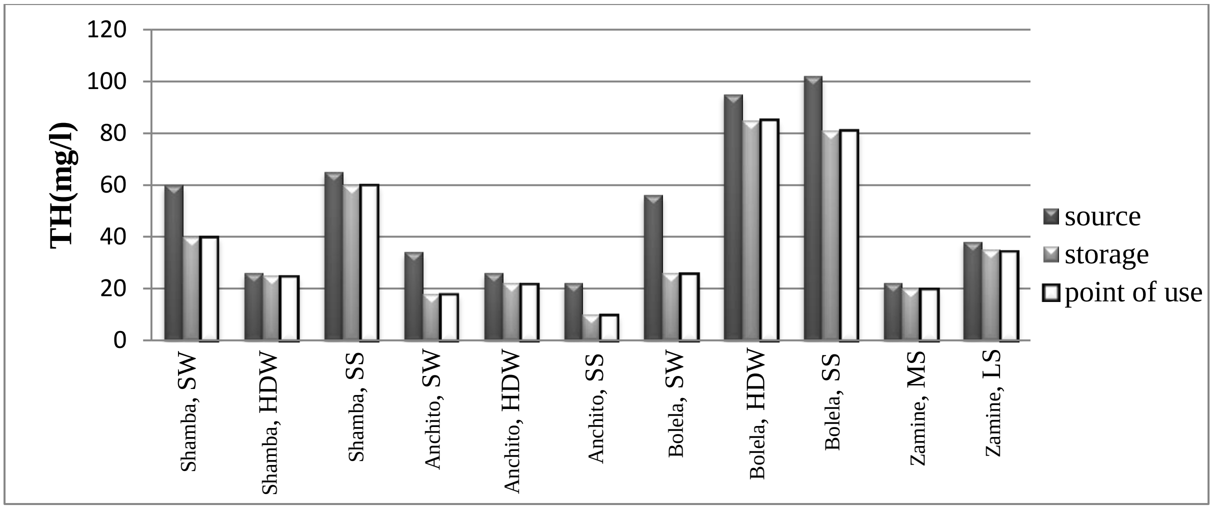

Figure 4-9 The value of TH at the source, storage and point of-use.

Nitrate and phosphate

The result of laboratory analysis revealed that the mean values of nitrate for the source, storage and point of-use were 1.91±0.87mg/l, 1.53±0.58mg/l and 1.53±0.58mg/l, respectively. The minimum and maximum values for nitrate were 1.1mg/l at Bolelachawkare kebele on-spot spring to 3.74mg/l Shamba kebele on-spot spring, respectively (Appendix 6 and 8). After storage, it has varied between 1mg/l and 2.3mg/l (Appendix 6 and 8). The laboratory result showed that within the acceptable limits of ES and WHO for potable water quality.

The result of laboratory analysis revealed that the mean values of phosphate for the source, storage and point of-use were 0.44±0.4mg/l, 0.4±0.18mg/l and 0.4±0.18mg/l respectively. The minimum and maximum values for phosphate were 0.2mg/l Bolelachawkare kebele hand dug well to 0.9mg/l Zaminenare kebele large spring, respectively (Appendix 8 and 9). The finding of this study was in agreement to previous research by Douhri et al (2015). The laboratory result showed that above the acceptable limits of ES and WHO for potable water quality. Statistical analysis showed that, the differences in the mean from source, storage and point of use value of nitrate and phosphate from sampled sites were not significant at $p < 0.05$ significant levels (Appendix 11).

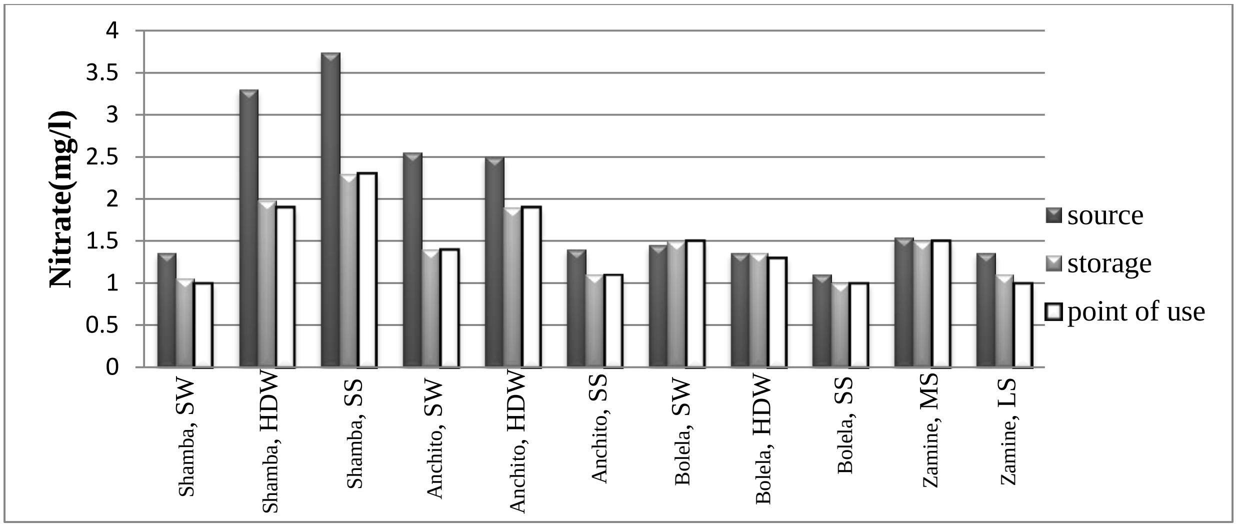

Figure 4-10 The value of Nitrate at the source, storage and point of-use.

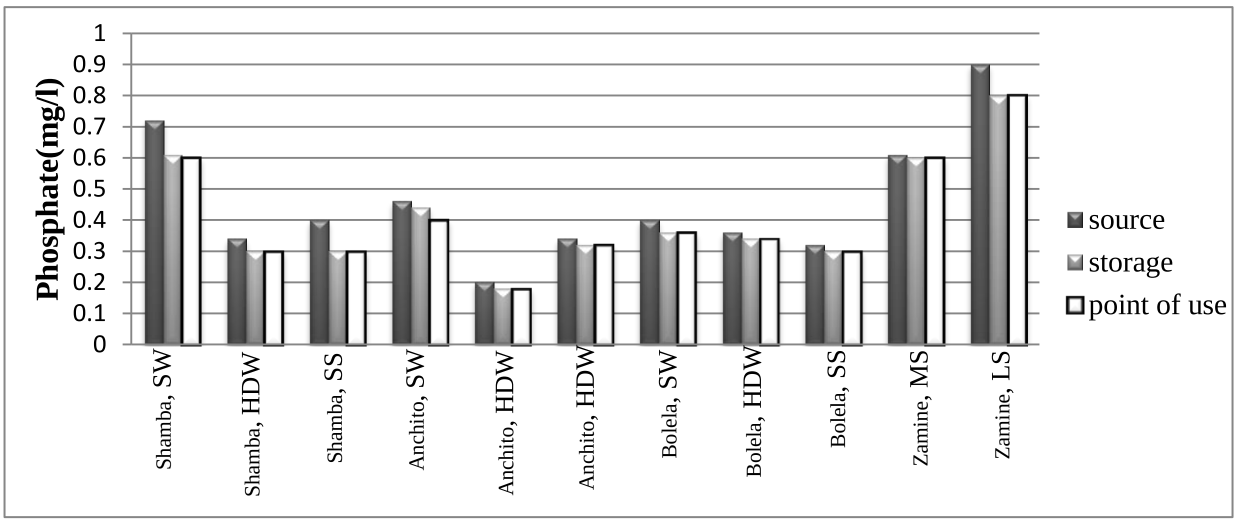

Figure 4-11 The value of phosphate at the source, storage and point of-use.

Chloride and Fluoride

The result of laboratory analysis revealed that the mean values of chloride for the source, storage and point of-use were 7.64±1.14mg/l, 7.29±1.02mg/l and 7.29±1.02mg/l, respectively. At the source, it varied between 6.38mg/l to 9.5mg/l and between 5.8mg/l to 9.3mg/l after storage (Appendix 8 and 9).

The laboratory result showed that mean value of Fluoride for source, storage and point of-use were 0.63±0.28mg/l, 0.59±0.288mg/l and 0.59±0.288mg/l, respectively. Statistical analysis showed that the differences in the mean of chloride and fluoride at the source, storage and point of-use sampled sites were not significant at $p<0.05$ significant levels (Appendix 11). All sampled test of chloride and Fluoride was within the acceptable limits of Ethiopia and WHO standards for potable water quality.

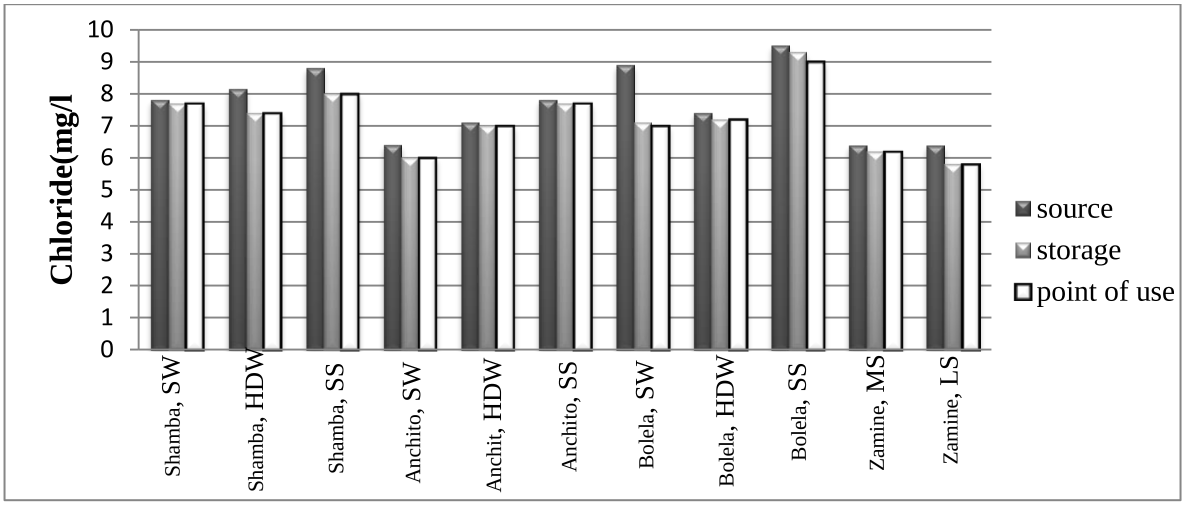

Figure 4-12 The value of chloride at the source, storage and point of-use.

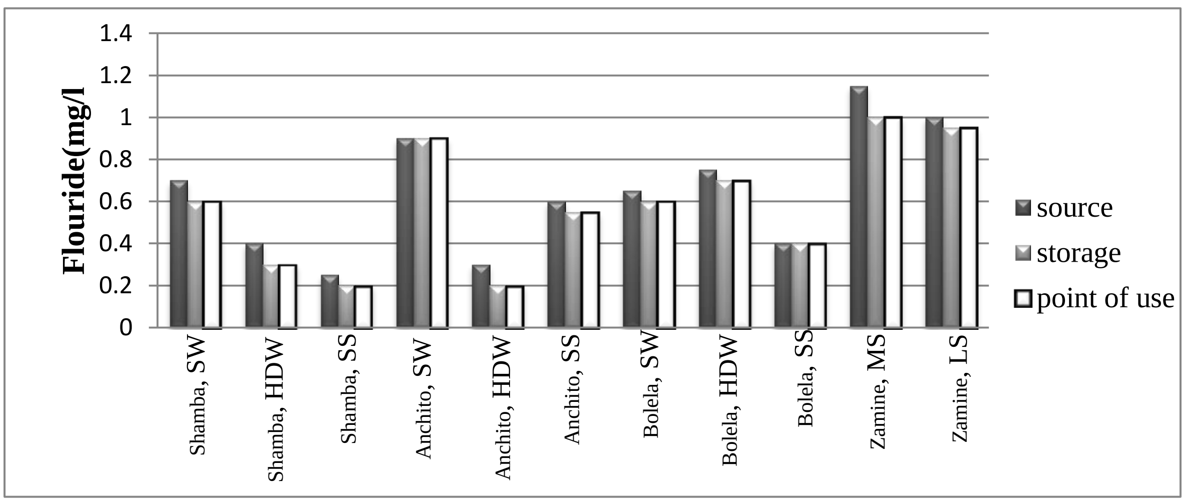

Figure 4-13 The value of fluoride at the source, storage and point of-use.

Iron and Magnesium

Tiny amount or trace levels of dissolved metals in surface water are essential for proper biological functioning. Many are important in basic physiological functions in both plants and animals, as blood components or cofactors in enzyme reactions (Dagnew et al, 2007). The registered mean concentration values of iron and magnesium for source to storage were (0.07±0.06mg/l and 0.06±0.06mg/l) to (10.89±1.6 and 8.9±1.2 mg/L), respectively. The statistical analysis showed that the mean difference from the source, storage and point of-use for iron and magnesium of the sampled sites were not significant at $p<0.05$ significant level (Appendix 11). The analyzed laboratory result of iron and magnesium concentration obtained from the sampled sites was below the maximum permissible limit of ES and WHO standards.

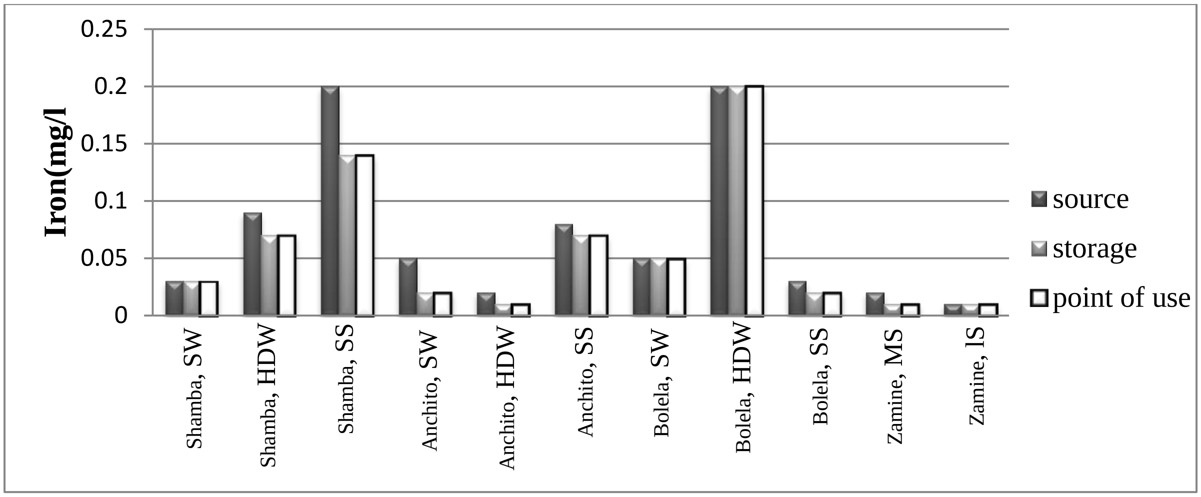

Figure 4-14 The value of Iron at the source, storage and point of-use.

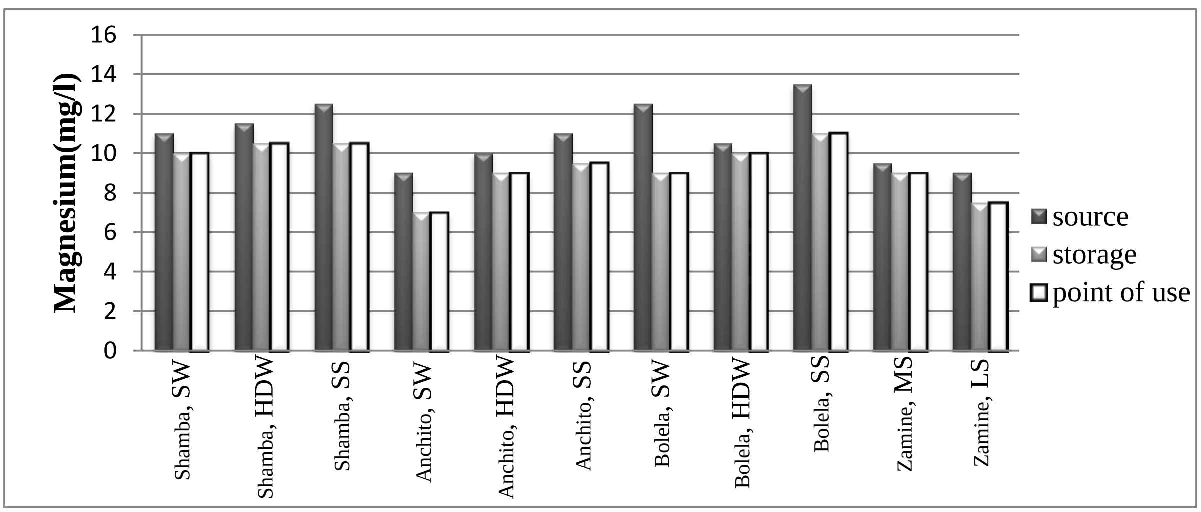

Figure 4-15 The value of magnesium at the source, storage and point of-use.

4.3.2. Bacteriological analysis for the source, storage and point of-use

Table 4-8 Mean value of bacteriological parameter for the source, storage and point of use.

Parameters	Units	Source		Storage		Point of-use		Standards	
		Mean	Std	Mean	Std	Mean	Std	ES	WHO
TC	CFU	9.36	5.12	14.27	6.85	17.72	8.02	0	0

For water to be potable, it must be free of any bacterial contaminants. An important indicator of water quality is the number of bacteria present in the water. Though it would be difficult to determine the presence of all bacteria in a sample, certain types of microorganisms can serve as indicators of pollution. Chief among these are the coliform bacteria, which survive better, longer and are easier to detect than other pathogens (Kegley and Andrews, 1998).

In Damot Sore Woreda, the contamination of water source with excreta from people or animals introduces a great variety of bacteria, viruses, protozoan worms. Insufficient protection of water sources or inadequate treatment, handling and storage, thus puts the community risk of contracting infectious diseases. An important problem is that the communities not perceive the risk of bacteriological contamination as the pollution is often not visible. Local people may value the taste and appearance of the water but not its bacteriological quality unless they understand the risk. Water quality parameter are very many in type and dependent on natural factors (geological, topographical, meteorological, hydrological and biological) and human intervention. Testing at households' storage water was done to characterize the quality of water coming out of the source and analysis at point of-use i.e. drinking cup done to characterize the quality of water coming out of household containers. For all of sites inspected, there was change in the total coliforms counts from source to household storage containers and from household storage containers to point of-use. The result obtained for the microbial analysis indicated that all the water samples contaminated with E.coli/thermo tolerant coliform. The least total coliform registered at Bolelachawkare kebele hand dug well were 2 CFU/100ml from the source, from the storage 4 CFU/100ml and from point of-use 5 CFU/100ml (Appendix 8). The maximum total coliform registered at Shamba kebele on-spot spring were 10 CFU/100ml from the source, 22 CFU/100ml from the storage and 30 CFU/100ml from the point of-use (Appendix 6). In addition, the mean values of total coliform for the source, storage and point of-use were 9.36±5.12CFU, 14.27±6.85CFU and 17.72±8.02CFU, respectively (Table 4.8). As a result, the differences in the mean from the source, storage and point of-use TC of the sampled sites were significant at $p<0.05$ significant level with $p= 0.024$(Appendix 11).

Similar research conducted by Mengesha et al (2004) also identifies the least coliform count seen was 13 coliform per 100 ml. None of the water line samples had zero coliform count per 100 ml, 21% had 18 and above coliforms per 100 ml. 21% of the samples also had 1-3 coliforms per 100 ml. E.Coli was found in 35.71% of the samples. In addition, previous researches have reported a significant deterioration of water quality after collection. Deterioration of the water quality has been detected during its storage and drinking cup at home in rural and urban areas throughout Africa, Asia and Latin America (Trevett et al., 2004; Hoque et al., 2006; Mc Garvey et al., 2008 and Kausar et al., 2012) among others.

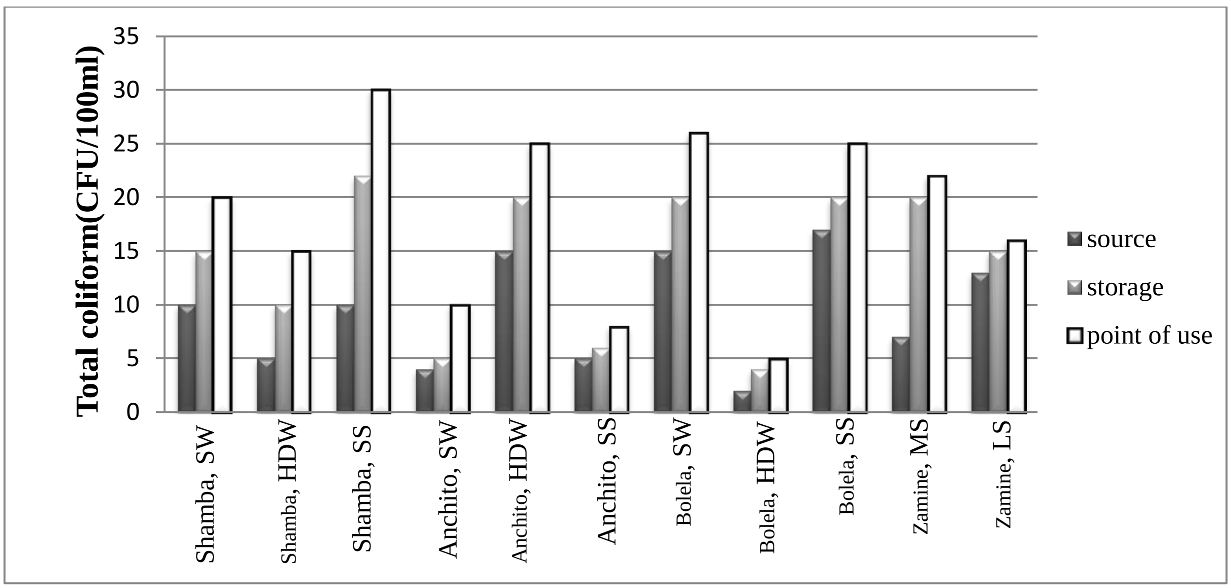

Figure 4-16 The value of TC at the source, storage and point of-use.

The medical officers in charge of the health centers in the Woreda confirmed frequent occurrence of water-borne diseases especially dysentery and diarrhea. They treat an average of thirty-eight cases of these diseases every week and the children are majorly affected (DSWHO, 2016). These cases showed that there is problem of potable water quality in the study area.

Research has shown that these bacteria cannot withstand high temperature (Schmidt and Cairn cross, 2008). It is therefore necessary to encourage the water user always boil their water before using it for domestic purposes. Of the thirty-three samples analyzed in this study, 100% complied with the Ethiopia standard and WHO guideline value for total coliforms. Compliance was significantly higher for source and household containers than for the point of use (100%).

In conclusion, the result of the laboratory analysis showed that all the physico-chemical water quality parameters considered in this study from all sampled sites varies from the source to household storage and showed the same value from household storage to point of use. However, the differences in the mean values of the sampled sites were not significant at $p<0.05$ significant level except temperature (Appendix 11). All bacteriological water quality analysis showed significant deterioration of water quality from source to household storage and from household storage to point of use. Although the Woreda's water supplies service office did not apply any kind of water treatment method on regular basis. It is therefore necessary to encourage the water user regularly add chlorine and boil their water before using it for domestic purposes and basic water supply; safe water storage and clean washing of storage containers and drinking cups are needed.

4.4. Water quality in dry and wet season

4.4.1. Physico-chemical analysis in dry and wet season

The water samples were analyzed for selected physico-chemical parameters during the dry month of January and wet month of April to study drinking water quality variation with the seasonal difference.

Table 4-9 The seasonal mean of physico-chemical parameters.

Parameters	Units	Dry season		Wet season		Standards	
		Mean	Std	Mean	Std	ES	WHO
Temp.	^oC	23.27	1.73	22	2.09	--	<15
EC	µs/cm	101	25.54	92.7	24.54	1500	1000
PH	PH	7.22	0.93	6.8	0.82	6.5-8.5	6.5-8.5
Turbidity	NTU	12.19	17.75	17.6	23.8	7	5
TDS	Mg/l	67.6	17	62	16.4	1000	1000
TH ($CaCO_3$)	Mg/l	49.63	28.65	44.36	27.27	300	300
Nitrate	Mg/l	1.91	0.92	2.15	0.92	50	50
Chloride	Mg/l	7.64	1.14	7.74	1.2	250	250
Fluoride	Mg/l	0.64	0.28	0.62	0.29	3	1.5
Iron	Mg/l	0.07	0.068	0.04	0.06	0.4	0.3
Magnesium	Mg/l	11.24	1.5	10.8	1.3	50	50
Phosphate	Mg/l	0.44	0.18	0.53	0.17	0.02	0.005

Temperature

Is one of the physical parameter used to evaluate quality of drinking water. The value of temperature varied from 22 to 27^{o}C and 20 to 26.5^{o}C in dry and wet season, respectively (Appendix 14 and 15). Mean concentrations were 23.27 ^{o}C in dry season and 22 ^{o}C in wet season. The statistical analysis showed that there was no significant difference at $P<0.05$ between the dry and wet seasons (Appendix 17). A similar study conducted in Ziway town, which is located near the study area showed a mean temperature of 23.2^{0}C from different water source samples (Kassahun, 2008). All the above-mentioned studies were from the tropics, where the climate is characterized by high temperature and rainfall. These factors might have contributed to the high temperature records of water samples that did not meet the WHO standard of < 15^{0}C.

pH and Turbidity

The concentration of pH varied from 5.8 to 8.5pH and 5.7 to 8.2pH in dry and wet season, respectively (Appendix 14 and 15). Mean concentrations were 7.22pH in dry season and 6.8pH in wet season. The statistical analysis showed that there was no significant difference at $P<0.05$ between the dry and wet seasons (Appendix 17). All the pH values collected at two seasons showed that within the permissible limit of ES and WHO drinking water guideline except

Shamba kebele hand dug well which is slightly acidic (5.8 during dry and 5.7 during wet season). The lower concentration during wet season was probably due to rainwater dilution.

Turbidity is one of the important physical parameter that affect not only the quality of water, but also other chemical and bacteriological parameters and efficiency of the treatment of water (WHO, 2008). High turbidity indicates the presence of organic suspended material, which promotes the growth of microorganism. It is used as a crude indicator of contamination with organisms such as *Cryptosporidia* (Momba et al., 2006). The concentration of turbidity varied from 0.57 to 49NTU and 1.8 to 67.5NTU in dry and wet season, respectively (Appendix 14 and 15). Mean concentrations were 12.9NTU in dry season and 17.6 NTU in wet season (Table 4.9). Similarly, the study conducted by Joseph (2013) mean turbidity values recorded for wet season wells were 14.50±21.51 NTU and that of the dry season recorded 4.01±4.96 NTU. Lower turbidity values during the dry season are probably due to less groundwater recharge and the filtration. The statistical analysis showed that there was no significant difference at $P<0.05$ between the dry and wet seasons (Appendix 17). All the turbidity values collected at different seasons showed that within the permissible limit of ES and WHO drinking water guideline except HDW and SS, SS and HDW at Shamba, Anchitochawkare and Bolelachawkare kebeles, respectively.

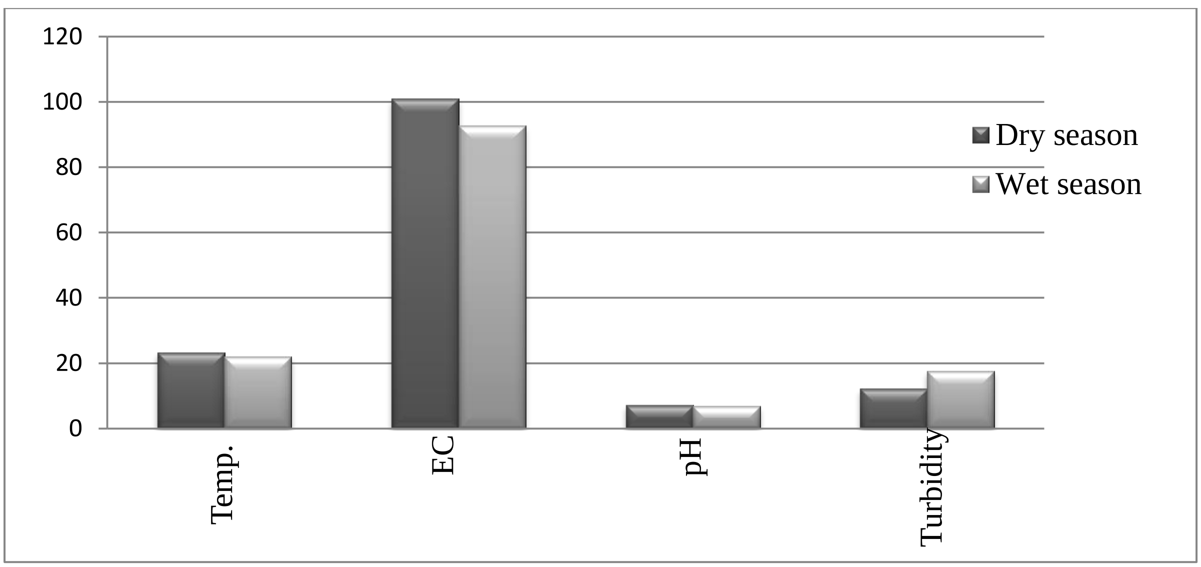

Figure 4-17 The value of physical parameters in dry and wet season

Electrical conductivity (EC) and Total dissolved solids (TDS)

The concentration of EC varied from 60.5 to 137.9μs/cm and 55 to 130μs/cm in dry and wet season, respectively (Appendix 14 and 15). Mean concentrations were 101μs/cm in dry season and 92.7μs/cm in wet season. This result is in agreement with previous study conducted in WA, Ghana by Joseph (2013) and in Blantyre district, Malawi by Mkandawire (2008). The statistical analysis showed that there was no significant difference at $P<0.05$ between the dry and wet seasons (Appendix 17). All the EC values collected at different seasons showed that within the permissible limit of ES and WHO drinking water guideline.

The concentration of TDS varied from 40.5 to 92.3mg/l and 36.8 to 87.1mg/l in dry and wet season, respectively (Appendix14 and 15). Mean concentrations were 67.6mg/l in dry season and 62mg/l in wet season. This result is in agreement with previous study conducted in WA, Ghana by Joseph (2013) and in Blantyre district, Malawi by Mkandawire (2008). The statistical analysis showed that there was no significant difference at $P<0.05$ between the dry and wet seasons (Appendix 17). All the TDS values collected at different seasons showed that within the permissible limit of ES and WHO drinking water guideline. The TDS values were lower in the wet season compared to the dry season probably due to the dilution effect of rainwater (Mkandawire, 2008).

Total hardness

The concentration of TH varied from 22 to 102mg/l and 18 to 94mg/l in dry and wet season, respectively (Appendix 14 and 15). Mean concentrations were 49.63mg/l in dry season and 44.3mg/l in wet season. This result is in agreement with previous study in Ruiru County, Kenya by Otieno et al (2015) in Blantyre district, Malawi by Mkandawire (2008). The statistical analysis showed that there was no significant difference at $P<0.05$ between the dry and wet seasons (Appendix 17). Lower value during wet season may due to dilution effect of calcium and magnesium ions. All the TH values collected at different seasons showed to be within the permissible limit of ES and WHO drinking water guideline.

Nitrate and Phosphate

The concentration of nitrate varied from 1.1 to 3.74mg/l and 1.2 to 3.87 mg/l in dry and wet season, respectively (Appendix 14 and 15). Mean concentrations were 1.91mg/l in dry season and 2.15mg/l in wet season. The statistical analysis showed that there was no significant difference at $P<0.05$ between the dry and wet seasons (Appendix 17). All the Nitrate values collected at different seasons showed to be within the permissible limit of ES and WHO drinking water guideline. In this study, the concentration of nitrate was at some extent increased in the wet season by 0.21mg/l. This was due to the organic wastes, surface runoff from agricultural land with fertilizer into the spring through the subsurface flow (Otieno et al., 2015). The value of nitrate content of water source samples measured in this study is less compared to the maximum values of 6.1 mg/l from the source of two wells of Debreziet (Desta, 2009) and 10.8mg/l and 12.9mg/L from source waters of Ziway town (Kassahun,2008).

The concentration of phosphate varied from 0.2 to 0.8mg/l and 0.3 to 0.9 mg/l in dry and wet season, respectively (Appendix 14 and 15). Mean concentrations were 0.44mg/l in dry season and 0.53 mg/l in wet season. The statistical analysis showed that there was no significant difference at $P<0.05$ between the dry and wet seasons (Appendix 17). The value increased by 0.07 mg/L. This was may be due to the use of detergents and soaps to wash their clothes and intensive agricultural activities around the source (Adimasu, 2015). Based on the current value obtained, the value of phosphate content of water source samples measured in this study was exceeded to the maximum permissible limit of ES and WHO guidelines.

Chloride and Fluoride

Mean concentrations of chloride were 7.64mg/l to 7.74mg/l in dry and wet season respectively. An increase in the mean value of chloride content of water may due to addition from human sewage, animal manure and agricultural wastes (WHO, 2008).

Mean concentration of fluoride were 0.64 to 0.62mg/l in dry and wet season, respectively. The statistical analysis showed that there was no significant difference at $P<0.05$ between the dry and wet seasons (Appendix 17). All the values of chloride and fluoride collected at different seasons showed that within the permissible limit of ES and WHO drinking water guideline.

Iron and Magnesium

The concentration of iron varied from 0.01 to 0.2mg/l and 0.01 to 0.2 mg/l in dry and wet season, respectively (Appendix 14 and 15). Mean concentrations were 0.07mg/l in dry season and

0.04mg/l in wet season. The statistical analysis showed that there was no significant difference at $P<0.05$ between the dry and wet seasons (Appendix 17). The lower concentration during wet weather was probably due to rainwater dilution. All the iron values collected at two seasons showed that within the permissible limit of ES and WHO drinking water guideline.

The concentration of magnesium varied from 9 to 13.5mg/l and 8 to 13 mg/l in dry and wet season, respectively (Appendix 14 and 15). Mean concentrations were 11.24mg/l in dry season and 10.8 mg/l in wet season. The lower concentration during wet weather was probably due to dilution. The statistical analysis showed that there was no significant difference $P<0.05$ between the dry and wet seasons (Appendix 17). All the magnesium values collected at two seasons showed that within the permissible limit of ES and WHO drinking water guideline.

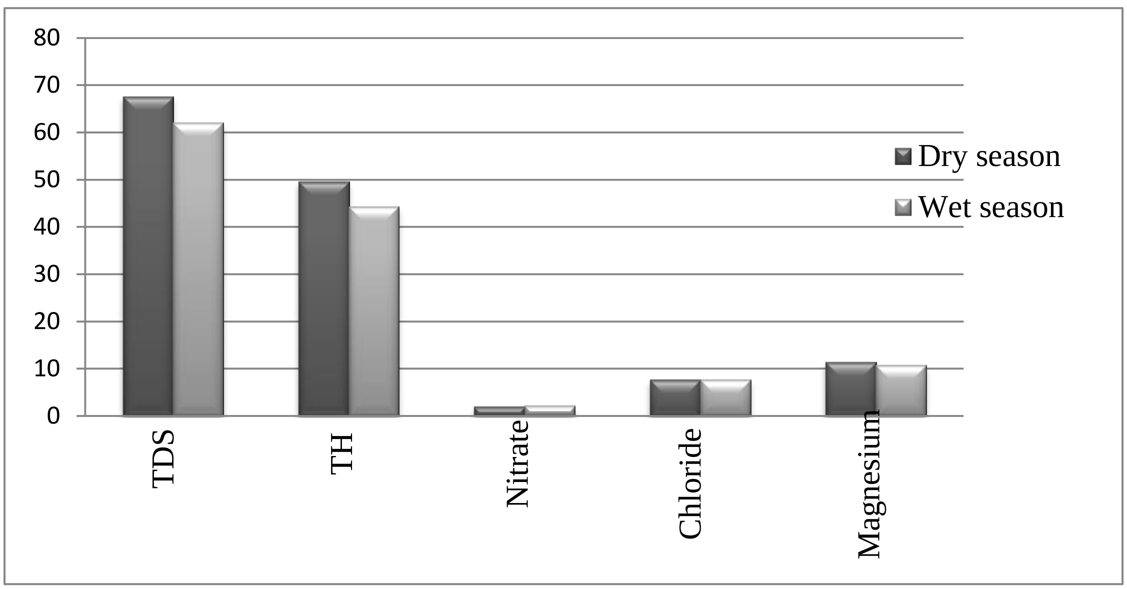

Figure 4-18 The value of chemical parameters in dry and wet season

4.4.2. Bacteriological analysis in dry and wet season

The water samples were analyzed for selected bacteriological parameter during the dry month of January and wet month of April to study drinking water quality variation with the seasonal difference.

Table 4-10 The seasonal mean of bacteriological parameter.

Parameters	Units	Dry season		Wet season		Standards	
		Mean	Std	Mean	Std	ES	WHO
TC	CFU	9.54	5.3	14	6.8	0	0

It is the critical issue in the quality of water in the study area and any areas of Ethiopia. Bacteriological analysis of water samples showed that all samples of water sources were positive for total coliforms in two rounds of triplicate sampling. The concentration of TC varied from 2 to 15 and 5 to 25 per 100ml in dry and wet season, respectively (Appendix 14 and 15). Mean concentrations were 9.5 per 100ml in dry season and 14 per 100ml in wet season. This indicates the presence of contamination in two seasons and the concentration of TC increase from dry to wet season. However, the statistical analysis showed that there was no significant difference $P<0.05$ between the dry and wet seasons (Appendix 17). In two different seasons the value was beyond the recommended maximum permissible limits of ES and WHO (ES, 2002 and WHO, 2008), zero/100 mL for the drinking.

The study conducted in Ruiru County, Kenya showed that the mean total coliform values for the sampled shallow well are 0.05 CFU/100ml (dry season) and 31.49 CFU/100ml (wet season) (Otieno et al, 2015). A similar study conducted by Getnet (2008) from Bahir Dar town showed that the analyzed water samples from the source of wet season had a mean total coliform count of 35.5 CFU/100ml which was above the acceptable level recommended by WHO (2008). The high amount of these coliform during the wet season could be because water availability favors the movement and reproduction of the organisms especially from surface run off, sewage and waste material (Otieno et al, 2015) and may be due to the site selection, inadequate protection of water sources and unhygienic practices near the water sources (Richards, 1996).

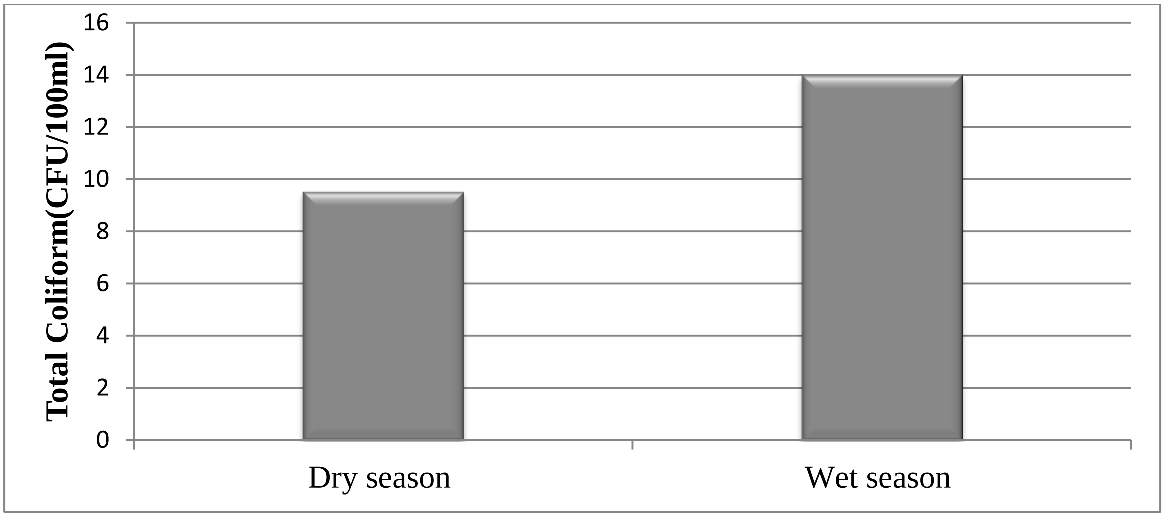

Figure 4-19 The value of total coliform in dry and wet season

4.5. Sanitary and hygienic practices

In addition to the analysis of physical, chemical and biological aspect, sanitary inspections carried out at all supply points visited during the study. Sanitary inspections are visual assessments of the infrastructure and environment surrounding a water supply, taking into account the condition, devices and practices in the water supply system that pose an actual or potential danger to drinking-water quality and thus to the health and well-being of the consumer.

4.5.1. Existence of latrines

The results presented in this section based on household survey and personal observation. The results revealed that 90% (74) of the respondents that are included in this survey reported the existence of latrine in the household compound. However, this does not mean that the sanitation coverage mostly and successfully achieved. Although the latrine coverage is 90%, sanitation problems like poor awareness on sanitary and hygienic practices, lack of using hand-washing facility after defecation and poor disposal method of wastes are still there. The results of household survey and personal observation revealed that the public toilets available in different parts of Damot Sore rural area are dirty and filled with faeces.

4.5.2. Types of latrines constructed

In the study area, three types of latrine commonly constructed; pit latrine with walls but without roof, pit latrine with closed wall and roof and open pit latrine without house. On the average, 39% (33) of the households had latrines with a wall and roof; 46.7% (38) of the respondents had pit latrines with closed walls but without roof, 14.3%(12) of the households had open pit latrines. Usually bowls used to avoid bad smell around the latrines. Moreover, covering might prevent bad smells from spreading beyond the latrine. However, bowls not covered in most latrines observed in the study area. Latrine with bowls covered is only 6 %(5). The sanitation technologies said to improve if those sanitation facilities prevent humans, animals and insects from coming in contact with human excreta (UNICEF, 2008). However, such improved technologies not mostly been observed in the study area. The sanitation condition is not pleasing as some of the toilets are simply made of local materials without any facilities. As sanitation is highly linked to water supply, people in the community are suffering from sanitation problems. Therefore, lack of proper access to sanitation is the major cause of potable water quality problem and spreading of diseases in Damot Sore Woreda, which are harmful to human life. This finding agreed with previous study by Tegegn (2009) in twenty villages of Ethiopia and Joseph (2013) in WA, Ghana. The correlation result of the association of the type of latrine with other sanitation influencing factors showed that there is positive relationship between them (Appendix 18).

Table 4-11 Type of pit latrine in the study area

S. No	Types of pit latrine	Bolela chawkare n= 22	Anchito chawkare n= 20	Shamba n= 23	Zamine nare n= 18	Total N=83
1	Pit latrine with walls but without roof	55.5 %	39 %	44.3 %	48 %	46.7%
2	Pit latrine with walls and roofs	34 %	51.7 %	45 %	25.5 %	39 %
3	Open pit latrine without house	10.5 %	9.3 %	10.7 %	26.5 %	14.3%

4.5.3. Disposing of liquid and solid wastes

Good hygiene practices (especially hand washing with soap after defecating and before preparing food, and safe disposal of children's faeces) prevent diarrhea (UNICEF, 2006). It has been reported that baby faeces that is not properly disposed might put household members at risk of diarrhea (Tumwine et al., 2003). Disposal of solid and liquid wastes in open field is a usual activity in the study area. During his stay in the study area, the researcher observed the people that were disposing wastes of different type in open field outside their houses. Of the total respondents, 27.7 % (23) used private sanitary pit to dispose waste generated from their house. The remaining 72.2% (60) of the respondents did not have private sanitary pit; as a result, they disposed the waste generated from their house including the baby feces anywhere else. Households that used the private sanitary pit for disposing wastes did not worry about the dimension of the pit and the frequency of disposing the compost from the pit. They said that they have enough space to construct another pit in their compound. As a result, they constructed pits of small dimension. This situation results in a continuous transmission of communicable diseases. This enabled to indicate the condition of environmental sanitation in Damot Sore Woreda mainly in relation to water supply and sanitation. The situation in most cases was very poor. Hence, there is a need to educate the people on how to handle the wastes properly and dispose off the waste in proper ways and places. This finding agreed with previous study by Tegegn (2009) in twenty villages of Ethiopia. The correlation result of the association of the disposing of liquid and solid wastes with other sanitation influencing factors showed that there is positive relationship between them (Appendix 18).

4.5.4. The habit of using pit latrines

The survey showed that if latrine was constructed, it did not mean it used regularly. Only 20% or less of those who constructed a latrine used it regularly. On average, about 35% of the respondents who had constructed a latrine used it rarely or not at all. The reasons for not using the latrine regularly were in order of importance: bad smell around the compound, feeling uncomfortable in using the latrine, and the large distance between agricultural fields and their home and latrine (Table 4.12). The correlation result of the association of the habit of using pit latrine with other sanitation influencing factors showed that there is positive relationship between them (Appendix 18).

Table 4-12 Reasons of the respondents who have latrine for not using it regularly

		Habit of using house pit latrine				
S. No	Questions reflected to respondents	Bolela chawkare n= 22	Anchito chawkare n= 20	Shamba n= 23	Zaminenare n= 18	Total N=83
1	Feel uncomfortable using latrine	36 %	29 %	34.8 %	31 %	32.4 %
2	Farther distance between farming place and home	7.5 %	11 %	14 %	22.7 %	13.8 %
3	Bad smell developed around the compound	56.5 %	60 %	51.2 %	46.3 %	53.5 %

4.5.5. Materials used for washing hands after defecation

More than 49 % of respondents in all the study area don't use water at all for hand washing after defecating (Table 4.13). 26% of the respondents were using water only, and the remaining were used water and ash (12.9%) or water and soap (11.8%) for hand washing after attending toilet. The number of respondents who do not use water at all after attending toilet was the smallest in Shamba and higher in Zaminenare kebeles. This result is different from the finding of Tehuledere woreda, northeast Ethiopia, i.e. is most of the households 141(73.4%) rinsed their collection containers and wash their hands 123(64.1%) before and after water collection and after defection (Seid et al., 2013).

Table 4-13 The hand washing materials after defecation

S. No	Washing material used after defection	Bolelachawkare n= 22	Anchitochawkare n= 20	Shamba n= 23	Zaminenare n= 18	Total N= 83
1	Water only	20.5%	29.7%	34%	20.8%	26.3%
2	Water and ash	12.5%	18%	13%	8%	12.9%
3	Water and soap	11%	8.5 %	17.4%	10.2%	11.8%
4	Don’t use water at all	56%	43.8%	35.6%	61%	49%

The number of households who were using water and soap after attending the toilet was small due to use of soap was limited because soap was reportedly expensive and was only used for laundry purposes. For those who used it for hand washing after attending toilet, soap was not kept at the toilet because of the fear that someone might visit the toilet and decide to take it. Majority of the households who did not use water for washing their hands after defecation were illiterate. Besides, they have poor awareness on hygienic practices. Therefore, awareness creation and educating the community about hygiene and sanitation with their combined impact on health at household level is of great importance.

Hygiene improvement is a comprehensive approach to prevent diarrheal disease by promoting improvements in hand washing, treatment and safe storage of water, sanitation, improved access to water and sanitation technologies and products, and fostering an enabling environment. Studies have documented that hand washing at critical times with soap reduce the risk of diarrheal diseases (Curtis and Cain cross, 2003).

Therefore, education alone does not motivate people to wash their hands regularly. Regular follow-up and provision of soap particularly those who lack income is required to encourage and strengthen this behavior. Soap is a critical component of effective hand washing. Therefore, consideration should give to provide soap particularly to those who lack income. Furthermore, follow up evaluations are important to assess the degree to which hygienic behaviors are adopted and continued. The correlation result of the association of the materials used for washing hands after defection with other sanitation influencing factors showed that there is positive relationship between them (Appendix 18).

5. CONCLUSION AND RECOMMENDATIONS

Based on the findings of the results presented in the preceding chapters, this chapter attempts to draw general conclusions and recommendations.

5.1. Conclusion

People in the study area largely depend on improved water sources developed from groundwater for drinking and other domestic activities. As observed from this research, Damot Sore Woreda rural water supply service could not meet water consumption per capita with existing capacity. At present, the coverage of water supply is only 46.5% of total population load per a single water points. The water source/point mapping of the Woreda also indicated that only 58.4% of the total area of the Woreda was covered with in 1.5 km distance. The existing water supply schemes are characterized by very low service coverage as only 28% and 68% of the respondents satisfied with provided amount and quality of water, respectively and poor operation and maintenance as 32% of the water supply services are non-functional. The data analysis showed that the Woreda water use at the household level significantly influenced by family size (p=1%), waiting time at the schemes (p=1%), distance to the schemes (p=5%) and functionality of the schemes (p=5%).

Water safety in a community depends on different factors i.e. from the quality of water at the source to transport, storage and handling practices at household level. The physico-chemical parameters showed that drinking water from the source to household storage decrease and it is the same from household containers to point of use. The variability analysis (ANOVA) test indicated that there were no significant differences for mean values of all physico-chemical parameters among various sampled points for the source, storage and point of use at $p<0.05$ significant levels with the exception of temperature($p=0.036$). However, total coliform increased in all sampled points from the source to storage and from storage to point of use. The variability analysis (ANOVA) test also indicated that there were significant differences for mean values of all bacteriological parameter among various sampled points of source, storage and point of use at $p<0.05$ significant level($p=0.024$).

In addition, the results of seasonal analysis showed that most of the parameters have higher mean values during the dry season, except for turbidity, nitrate, chloride, phosphate and TC, which had higher mean values during the wet season. The variability analysis (ANOVA) test indicated that there were no significant differences for mean values of all physico-chemical and bacteriological parameters of dry and wet season among various sampled sites at $p<0.05$ significant levels.

Most of the physical and chemical parameters measured were within the recommended range of ES and WHO standards. Except temperature (at all samples $> 15^oC$), turbidity (hand dug well =49NTU, on-spot spring =22NTU and hand dug well =42.3NTU at Shamba, Anchitochawkare and Bolelachawkare kebeles, respectively), phosphate (at all samples $>$ 0.02mg/l) and pH (HDW =5.6pH at Shamba kebele), which were found to be unacceptably high in case of temperature, turbidity and phosphate and unacceptably low in the case of pH. Unlike the physico-chemical parameters, bacteriological analysis showed that the studied source, storage, point of use, dry and wet season's drinking water were found to be contaminated as it was indicated by high total coliform (all samples $>$0 CFU/100mg). This study demonstrated that supply of water alone could not guarantee that the water at the source, storage and in the household for drinking purpose is safe as well. An irregular and inadequate water supply compels people to store water for long periods and microbial contamination was found to be higher in stored and point of use water than in source water.

Sanitation and hygienic situation in the Woreda was not good and encouraging. The finding revealed that lack of private sanitary pit, poor hand washing practice, lack of communal landfill, improper handling and disposal of wastes and lack of drainage facilities around water points were identified as the major factors responsible for poor sanitation and hygiene and which contributes to the deterioration of drinking water quality in the Woreda. This situation revealed that Damot Sore Woreda was not provided with access to adequate water supply and basic sanitation.

5.2. Recommendations

Based on the findings discussed above, the following recommendations can be drawn to enhance improved water supply coverage and its quality at source and household level. The possible areas of intervention include:

- The development of new water source and expansion of the existing sources should take place in order to improve low water provision and consumption of the Woreda (l/p/d).
- The available quantity of water from all sources of supply schemes should be accessed to all the people on fair distribution basis.
- Despite maintaining strong physical structure, many schemes are in need of different types of repair. Therefore, the management system needs to review its approaches on how to establish institutional mechanisms related to operation and maintenance and ensure that they remain active throughout the designated lifespan of each scheme.
- Attempts are necessary to improve the safety of all water supply schemes from the source. This can be made by source disinfection mechanisms like chlorination, point of use disinfection mechanisms such as boiling and other household water treatment measures to decrease the bacteriological health hazards and regular cleaning of water containers and drinking cup system may improve the conditions significantly.
- Giving sustainable access to safe drinking water needs to include increased availability of consistent water supplies and a means of ensuring that water is safe up to the time it is consumed and there is a need to build community capacity on water treatment to improve water quality.
- To sustain service delivery of water points by maintaining good quality water, water point construction should follow proper planning complemented by design treatments such as locating water points at reasonable distance from potentially contaminating sources such as pit latrines and runoff and proper construction of spring capping structure.
- More private sanitary pit and communal landfills have to be established to ensure proper solid and liquid waste collection.
- Many awareness creation activities should be done on sanitation and hygiene through all concerned bodies and extension workers for not only preparing latrines but also regular use of the latrines and hand washing practices.
- The present work is limited to few physico-chemical and bacteriological parameters and sampling frequency. Therefore, year round sampling and analysis of additional water quality parameters should be undertaken.

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APPENDICES

Appendix 1 Socio-demographic characteristics of respondents

S. No	Characteristics	Frequency	Percentage
1.	**Gender (N=83)**		
	Male	40	48.2
	Female	43	51.8
2.	**Age category**		
	<20	5	6
	20-29	16	19.2
	30-39	28	33.7
	40-49	18	21.7
	50-59	11	13.3
	>60	5	6
3.	**Marital status**		
	Married	66	79.5
	Single	11	13.2
	Divorce	6	7.2
4.	**Educational level**		
	Not educated	11	13.3
	Non formal education	14	16.9
	Primary	32	38.6
	Secondary	20	24.1
	College	6	7.2
5.	**Occupation**		
	Farming	58	69.9
	Daily labor	11	13.3
	Small scale business	6	7.2
	Government employee	8	9.6
6.	**Household size**		
	≤ 4	8	9.6
	5	15	18.1
	6	28	33.7
	7	15	18
	8	11	13.3
	≥9	6	7.2

Appendix 2 Multiple linear regression adjusted R square

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.996[a]	.992	.991	.45145	.992	901.946	10	72	.000

Appendix 3 ANOVA for multiple linear regressions

Model	Sum of square	Df	Mean square	F	Sig.
Regression	1838.241	10	183.824	901.946	.000[b]
Residual	14.674	72	.204		
Total	1852.916	82			

a. Dependent Variable: per capita water consumption liter per day
b. Predictors: (Constant), time to fetch in minute, education , functionality of the water supply scheme, purpose of using potable water, habit of household water use, income level birr per month, point characterization, consumer satisfaction, distance to the scheme in meter, size of household in number.

Appendix 4 Multiple linear regression model result

Model	Unstandardized coefficient		Standardized coefficient	T	Sig.	Collinearity statistics	
	B	Std. error	Beta			Tolerance	VIF
(Constant)	27.991	.985		28.418	.000		
Education	-.055	.104	-.006	-.524	.602	.911	1.097
income level birr /month	.211	.392	.025	0.538	.129	.403	2.479
functionality of the water supply scheme	.295	.117	.031	2.519	.014	.719	1.390
consumer satisfaction	.260	.201	.026	1.292	.200	.277	3.615
purpose of using potable water	-.193	.170	-.019	-1.131	.262	.411	2.433
distance to the scheme in meter	-.001	.00037	-.068	-2.651	.010	.170	5.893
point characterization	.046	.180	.005	.257	.798	.315	3.170
habit of HH water use	.074	.160	.007	.464	.644	.426	2.345
size of HH in number	-.813	.085	-.415	-9.543	.000	.058	1.227
time to fetch in minute	-.255	.026	-.486	-9.768	.000	.044	2.532

Appendix 5 Sampled water supply schemes for coverage and quality analysis

Kebeles Name	Village Name	Type of water supply	GPS x	GPS y	GPS z	Current status	Yield (L/ s)
Zaminenare	Shoke	Medium spring	348428	773994	1762	Functional	0.062
	Giyaqomo	Large spring	347829	773573	1668	Functional	0.25
Shamba	Ashalicho	Hand dug well	354085	765085	2005	Functional	0.2
	Soripela	Shallow well	353056	766020	2010	Functional	0.27
	Qeme	On spot spring	355029	765529	1982	Functional	0.078
Anchitochawkare	Chawkare	Hand dug well	354148	766378	2004	Functional	0.05
	Dingama	Shallow well	354513	768136	1976	Functional	0.14
	Borixancho	On spot spring	353776	767194	1987	Functional	0.15
Bolelachawkare	Buzo	Hand dug well	349983	763103	2055	Functional	0.28
	Chawkare	Shallow well	351130	763926	2058	Functional	0.25
	Demba	On spot spring	350986	764612	2018	Functional	0.01

Appendix 6 Mean value of Physico-chemical and Bacteriological analysis of sample points of source, storage and point of use from Shamba kebele.

		Shallow well			HDW from			On-spot spring			ES	WHO
Parameters	Units	Source	Storage	Point of use	Source	Storage	Point of use	Source	Storage	Point of use	Standards	Standards
Physical												
Temp.	^oC	24	21	21	22	21	21	23	21	21	<15	-
EC	µs/cm	137.9	121	120	81	69.8	69	60.5	50	50	1500	1000
PH	PH	8	7.3	7.3	5.8	5.6	5.6	6.8	6.6	6.6	6.5-8.5	6.5-8.5
Turbidity	NTU	1.79	1.5	1.49	11.1	9.5	9.4	49	45	45	7	5
Chemical												
TDS	Mg/l	92.3	81	81	54.3	46.7	46.7	40.5	33.5	33.5	1000	1000
TH (CaCO3)	Mg/l	60	40	40	26	25	25	65	60	60	300	300
Nitrate	Mg/l	1.36	1.05	1	3.3	1.98	1.9	3.74	2.3	2.3	50	50
Chloride	Mg/l	7.8	7.7	7.7	8.15	7.4	7.4	8.8	8	8	250	250
Fluoride	Mg/l	0.7	0.6	0.6	0.4	0.3	0.3	0.25	0.2	0.2	3	1.5
Iron	Mg/l	0.03	0.03	0.03	0.09	0.07	0.07	0.2	0.14	0.14	0.4	0.3
Magnesium	Mg/l	11	10	10	12.5	10.5	10.5	13	10.5	10.5	50	50
Phosphate	Mg/l	0.72	0.61	0.6	0.34	0.3	0.3	0.4	0.3	0.3	0.02	0.005
Biological												
E.coli/TTC	CFU/ 100ml	10	15	20	5	10	15	10	22	30	0/100	0/100

Appendix 7 Mean value of Physico-chemical and Bacteriological analysis of sampling points of source, storage and point of use from Anchitochawkare kebele.

		Shallow well			HDW			On-spot spring			ES	WHO
Parameters	Units	Source	Storage	Point of use	Source	Storage	Point of use	Source	Storage	Point of use	Standards	Standards
Physical												
Temp.	^oC	22	20	20	23	22	22	22	21	21	<15	-
EC	(µs/cm)	112.3	92	92	136.6	101.8	101	70.4	55	55	1500	1000
PH	PH	8	7.9	7.9	6.9	6.8	6.8	7.6	7.5	7.5	6.5-8.5	6.5-8.5
Turbidity	NTU	1.96	1.75	1.7	0.65	0.6	0.6	22	19	19	7	5
Chemical												
TDS	Mg/l	75.2	61.6	61	91.5	68.2	68	47.3	36.8	36.8	1000	1000
TH ($CaCO_3$)	Mg/l	34	18	18	26	22	22	22	10	10	300	300
Nitrate	Mg/l	2.55	1.4	1.4	2.5	1.9	1.9	1.4	1.1	1.1	50	50
Chloride	Mg/l	6.4	6	6	7.1	7	7	7.8	7.7	7.7	250	250
Fluoride	Mg/l	0.9	0.9	0.9	0.3	0.2	0.2	0.6	0.55	0.55	3	1.5
Iron	Mg/l	0.05	0.02	0.02	0.02	0.01	0.01	0.08	0.07	0.07	0.4	0.3
Magnesium	Mg/l	9.3	7	7	10.5	9	9	11.5	9.5	9.5	50	50
Phosphate	Mg/l	0.46	0.44	0.4	0.2	0.18	0.18	0.34	0.32	0.32	0.02	0.005
Biological												
E.coli/TTC	CFU/ 100 ml	4	5	10	15	20	25	5	6	8	0/100	0/100

Appendix 8 Mean value of Physico-chemical and Bacteriological analysis of sampling points of source, storage and point of use from Bolelachawkare kebele.

		Shallow well			HDW			On-spot spring			ES	WHO
Parameters	Units	Source	Storage	Point of use	Source	Storage	Point of use	Source	Storage	Point of use	Standards	Standards
Physical												
Temp.	^{o}C	23	22	22	22	20	20	22	21	21	<15	-
EC	µs/cm	95.5	82	82.5	92.5	83	83	90.3	70.2	70	1500	1000
PH	PH	8.3	7.8	7.8	8.5	8.4	8.4	6.7	6.8	6.8	6.5-8.5	6.5-8.5
Turbidity	NTU	1.2	1	1	42.3	36	35	0.57	0.55	0.55	7	5
Chemical												
TDS	Mg/l	61.7	55	55	63.9	55.6	55.6	60.5	47	47	1000	1000
TH ($CaCO_3$)	Mg/l	56	26	26	95	85	85	102	82	82	300	300
Nitrate	Mg/l	1.55	1.5	1.5	1.36	1.36	1.3	1.1	1	1	50	50
Chloride	Mg/l	8.9	7.1	7	7.4	7.2	7.2	9.5	9.3	9	250	250
Fluoride	Mg/l	0.65	0.6	0.6	0.75	0.7	0.7	0.4	0.4	0.4	3	1.5
Iron	Mg/l	0.05	0.05	0.05	0.21	0.2	0.2	0.03	0.02	0.02	0.4	0.3
Magnesium	Mg/l	12	9	9	11	10	10	13.5	8	8	50	50
Phosphate	Mg/l	0.4	0.36	0.36	0.36	0.34	0.34	0.32	0.3	0.3	0.02	0.005
Biological												
E.coli/TTC	CFU/ 100ml	15	20	26	2	4	5	17	20	25	0/10	0/100

Appendix 9 Mean value of Physico-chemical and Bacteriological analysis of sampling points of source, storage and point of use from Zaminenare kebele.

		Medium spring			Large spring			ES	WH O
Parameters	Units	Source	Storage	Point of use	Source	Storage	Point of use	Standards	Standards
Physical									
Temp.	^{o}C	26	24	24	27	25	25	<15	-
EC	PH	116.5	99.5	99	118	75	75	1500	1000
PH	(μs/cm)	6.12	6	6	6.9	6.7	6.6	6.5-8.5	6.5-8.5
Turbidity	(FAU)	1.8	1.5	1.5	2.1	1.8	1.8	7	5
Chemical									
TDS	Mg/l	78	67.6	67.5	79.2	50.2	50	1000	1000
TH (CaCO3)	Mg/l	22	20	20	38	35	34.5	300	300
Nitrate	Mg/l	1.54	1.5	1.5	1.36	1.1	1	50	50
Chloride	Mg/l	6.38	6.2	6.2	6.38	5.8	5.8	250	250
Fluoride	Mg/l	1.15	1	1	1	0.95	0.95	3	1.5
Iron	Mg/l	0.02	0.01	0.01	0.01	0.01	0.01	0.4	0.3
Magnesium	Mg/l	9.5	9	9	9	7.5	7.5	50	50
Phosphate	Mg/l	0.61	0.6	0.6	0.9	0.8	0.8	0.02	0.005
Biological									
E.coli/TTC	CFU/ 100ml	7	20	22	13	15	16	0/100	0/100

Appendix 10 Descriptive values for the source, storage and point of use

Parameters		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Temperature	Source	11	23.2727	1.73729	.52381	22.1056	24.4399	22.00	27.00
	storage	11	21.6364	1.56670	.47238	20.5838	22.6889	20.00	25.00
	point of use	11	21.6364	1.56670	.47238	20.5838	22.6889	20.00	25.00
	Total	33	22.1818	1.75810	.30605	21.5584	22.8052	20.00	27.00
EC	Source	11	100.836	25.54550	7.70226	83.6747	117.998	60.00	137.90
	storage	11	81.7091	20.95736	6.31888	67.6297	95.7884	50.00	121.00
	point of use	11	81.7091	20.95736	6.31888	67.6297	95.7884	50.00	121.00
	Total	33	88.0848	23.71238	4.12780	79.6768	96.4929	50.00	137.90
pH	Source	11	7.2182	.93147	.28085	6.5924	7.8440	5.60	8.50
	storage	11	7.0455	.83590	.25203	6.4839	7.6070	5.60	8.40
	point of use	11	7.0455	.83590	.25203	6.4839	7.6070	5.60	8.40
	Total	33	7.1030	.84539	.14716	6.8033	7.4028	5.60	8.50
Turbidity	Source	11	12.1882	17.75616	5.35368	.2594	24.1169	.57	49.00
	storage	11	10.7491	15.85523	4.78053	.0974	21.4008	.55	45.00
	point of use	11	10.7491	15.85523	4.78053	.0974	21.4008	.55	45.00
	Total	33	11.2288	16.00368	2.78588	5.5541	16.9034	.55	49.00
TDS	Source	11	67.3909	17.19881	5.18563	55.8366	78.9452	40.00	92.30
	storage	11	54.6909	14.15976	4.26933	45.1783	64.2036	33.00	81.00
	point of use	11	54.6909	14.15976	4.26933	45.1783	64.2036	33.00	81.00
	Total	33	58.9242	15.95968	2.77822	53.2652	64.5833	33.00	92.30
TH	Source	11	49.6364	28.65056	8.63847	30.3887	68.8841	22.00	102.00
	storage	11	39.3636	25.60966	7.72160	22.1588	56.5684	10.00	85.00
	point of use	11	39.3636	25.60966	7.72160	22.1588	56.5684	10.00	85.00
	Total	33	42.7879	26.27946	4.57467	33.4696	52.1062	10.00	102.00
Nitrate	Source	11	1.9155	.87539	.26394	1.3274	2.5035	1.10	3.70
	storage	11	1.5373	.58710	.17702	1.1429	1.9317	1.00	3.00
	point of use	11	1.5373	.58710	.17702	1.1429	1.9317	1.00	3.00
	Total	33	1.6633	.69834	.12156	1.4157	1.9110	1.00	3.70
Chloride	Source	11	7.6455	1.14137	.34414	6.8787	8.4122	6.00	9.50
	storage	11	7.2909	1.02123	.30791	6.6048	7.9770	5.80	9.30
	point of use	11	7.2909	1.02123	.30791	6.6048	7.9770	5.80	9.30
	Total	33	7.4091	1.04294	.18155	7.0393	7.7789	5.80	9.50

Parameters		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower	Upper		
Fluoride	Source	11	.6318	.28572	.08615	.4399	.8238	.20	1.10
	storage	11	.5909	.28002	.08443	.4028	.7790	.20	1.00
	point of use	11	.5909	.28002	.08443	.4028	.7790	.20	1.00
	Total	33	.6045	.27368	.04764	.5075	.7016	.20	1.10
Magnesium	Source	11	10.8909	1.61273	.48626	9.8075	11.9744	9.00	13.50
	storage	11	8.9545	1.27386	.38408	8.0988	9.8103	7.00	10.50
	point of use	11	8.9545	1.27386	.38408	8.0988	9.8103	7.00	10.50
	Total	33	9.6000	1.63898	.28531	9.0188	10.1812	7.00	13.50
Iron	Source	11	.0700	.06914	.02085	.0236	.1164	.01	.20
	storage	11	.0600	.06245	.01883	.0180	.1020	.01	.20
	point of use	11	.0600	.06245	.01883	.0180	.1020	.01	.20
	Total	33	.0633	.06288	.01095	.0410	.0856	.01	.20
Phosphate	Source	11	.4418	.18814	.05673	.3154	.5682	.20	.80
	storage	11	.4091	.18360	.05536	.2857	.5324	.18	.80
	point of use	11	.4091	.18360	.05536	.2857	.5324	.18	.80
	Total	33	.4200	.17993	.03132	.3562	.4838	.18	.80
TC	Source	11	9.3636	5.12392	1.54492	5.9213	12.8059	2.00	17.00
	storage	11	14.2727	6.85698	2.06746	9.6661	18.8793	4.00	22.00
	point of use	11	17.7273	8.02609	2.41996	12.3353	23.1193	5.00	30.00
	Total	33	13.7879	7.42781	1.29302	11.1541	16.4217	2.00	30.00

Appendix 11 ANOVA results for the source, storage and point of use

		Sum of Squares	Df	Mean Square	F	Sig.
Temperature	Between Groups	19.636	2	9.818	3.716	.036
	Within Groups	79.273	30	2.642		
	Total	98.909	32			
EC	Between Groups	2682.919	2	1341.459	2.629	.089
	Within Groups	15309.944	30	510.331		
	Total	17992.862	32			
Ph	Between Groups	.219	2	.109	.145	.866
	Within Groups	22.651	30	.755		
	Total	22.870	32			
Turbidity	Between Groups	15.187	2	7.594	.028	.973
	Within Groups	8180.582	30	272.686		
	Total	8195.769	32			
TDS	Between Groups	1182.793	2	591.397	2.546	.095
	Within Groups	6967.967	30	232.266		
	Total	8150.761	32			
TH	Between Groups	773.879	2	386.939	.544	.586
	Within Groups	21325.636	30	710.855		
	Total	22099.515	32			
Nitrate	Between Groups	1.049	2	.524	1.081	.352
	Within Groups	14.557	30	.485		
	Total	15.606	32			
Chloride	Between Groups	.922	2	.461	.408	.669
	Within Groups	33.885	30	1.130		
	Total	34.807	32			
Fluoride	Between Groups	.012	2	.006	.077	.926
	Within Groups	2.385	30	.079		
	Total	2.397	32			
Magnesium	Between Groups	27.496	2	13.748	7.055	.093
	Within Groups	58.464	30	1.949		
	Total	85.960	32			
Iron	Between Groups	.001	2	.000	.087	.917
	Within Groups	.126	30	.004		
	Total	.127	32			
Phosphate	Between Groups	.008	2	.004	.115	.892
	Within Groups	1.028	30	.034		
	Total	1.036	32			
TC	Between Groups	388.606	2	194.303	4.233	.024
	Within Groups	1376.909	30	45.897		
	Total	1765.515	32			

Appendix 12 Multiple Comparisons table for the source, storage and point of use

Tukey HSD

Dependent Variable	(I) samples taken	(J) samples taken	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower	Upper B
Temp.	source	Storage	1.63636	.69314	.063	-.0724	3.3451
		point of use	1.63636	.69314	.063	-.0724	3.3451
	storage	Source	-1.63636	.69314	.063	-3.3451	.0724
		point of use	.00000	.69314	1.000	-1.7088	1.7088
	point of use	Source	-1.63636	.69314	.063	-3.3451	.0724
		Storage	.00000	.69314	1.000	-1.7088	1.7088
EC	source	Storage	19.12727	9.63263	.133	-4.6198	42.8743
		point of use	19.12727	9.63263	.133	-4.6198	42.8743
	storage	Source	-19.12727	9.63263	.133	-42.8743	4.6198
		point of use	.00000	9.63263	1.000	-23.7470	23.7470
	point of use	Source	-19.12727	9.63263	.133	-42.8743	4.6198
		Storage	.00000	9.63263	1.000	-23.7470	23.7470
pH	source	Storage	.17273	.37051	.888	-.7407	1.0861
		point of use	.17273	.37051	.888	-.7407	1.0861
	storage	Source	-.17273	.37051	.888	-1.0861	.7407
		point of use	.00000	.37051	1.000	-.9134	.9134
	point of use	Source	-.17273	.37051	.888	-1.0861	.7407
		Storage	.00000	.37051	1.000	-.9134	.9134
Turbidity	source	Storage	1.43909	7.04126	.977	-15.9195	18.7977
		point of use	1.43909	7.04126	.977	-15.9195	18.7977
	storage	Source	-1.43909	7.04126	.977	-18.7977	15.9195
		point of use	.00000	7.04126	1.000	-17.3586	17.3586
	point of use	Source	-1.43909	7.04126	.977	-18.7977	15.9195
		Storage	.00000	7.04126	1.000	-17.3586	17.3586
TDS	source	Storage	12.70000	6.49847	.141	-3.3205	28.7205
		point of use	12.70000	6.49847	.141	-3.3205	28.7205
	storage	Source	-12.70000	6.49847	.141	-28.7205	3.3205
		point of use	.00000	6.49847	1.000	-16.0205	16.0205
	point of use	Source	-12.70000	6.49847	.141	-28.7205	3.3205
		Storage	.00000	6.49847	1.000	-16.0205	16.0205
TH	source	Storage	10.27273	11.368	.642	-17.7541	38.2995
		point of use	10.27273	11.3686	.642	-17.7541	38.2995
	storage	Source	-10.27273	11.3686	.642	-38.2995	17.7541
		point of use	.00000	11.3686	1.000	-28.0268	28.0268
	point of use	Source	-10.27273	11.3686	.642	-38.2995	17.7541
		Storage	.00000	11.3686	1.000	-28.0268	28.0268
Nitrate	source	Storage	.37818	.29702	.421	-.3541	1.1104
		point of use	.37818	.29702	.421	-.3541	1.1104
	storage	Source	-.37818	.29702	.421	-1.1104	.3541
		point of use	.00000	.29702	1.000	-.7322	.7322
	point of use	Source	-.37818	.29702	.421	-1.1104	.3541
		Storage	.00000	.29702	1.000	-.7322	.7322

Dependent Variable	(I) samples taken	(J) samples taken	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower	Upper B
Chloride	Source	point of use	.3545	.4531	.717	-.7627	1.4717
	Storage	Source	-.3545	.4531	.717	-1.4717	.7627
		point of use	.00000	.45317	1.000	-1.1172	1.1172
	point of use	Source	-.35455	.45317	.717	-1.4717	.7627
		Storage	.00000	.45317	1.000	-1.1172	1.1172
Fluoride	Source	Storage	.04091	.12022	.938	-.2555	.3373
		point of use	.04091	.12022	.938	-.2555	.3373
	Storage	Source	-.04091	.12022	.938	-.3373	.2555
		point of use	.00000	.12022	1.000	-.2964	.2964
	point of use	Source	-.04091	.12022	.938	-.3373	.2555
		Storage	.00000	.12022	1.000	-.2964	.2964
Magnesium	Source	Storage	1.93636	.59525	.08	.4689	3.4038
		point of use	1.93636	.59525	.08	.4689	3.4038
	Storage	Source	-1.93636	.59525	.08	-3.4038	-.4689
		point of use	.00000	.59525	1.000	-1.4675	1.4675
	point of use	Source	-1.93636*	.59525	.08	-3.4038	-.4689
		Storage	.00000	.59525	1.000	-1.4675	1.4675
Iron	Source	Storage	.01000	.02761	.930	-.0581	.0781
		point of use	.01000	.02761	.930	-.0581	.0781
	Storage	Source	-.01000	.02761	.930	-.0781	.0581
		point of use	.00000	.02761	1.000	-.0681	.0681
	point of use	Source	-.01000	.02761	.930	-.0781	.0581
		Storage	.00000	.02761	1.000	-.0681	.0681
Phosphate	source	Storage	.03273	.07894	.910	-.1619	.2273
		point of use	.03273	.07894	.910	-.1619	.2273
	storage	Source	-.03273	.07894	.910	-.2273	.1619
		point of use	.00000	.07894	1.000	-.1946	.1946
	point of use	Source	-.03273	.07894	.910	-.2273	.1619
		Storage	.00000	.07894	1.000	-.1946	.1946
TC	source	Storage	-4.90909	2.88875	.222	-12.0307	2.2125
		point of use	-8.36364*	2.88875	.019	-15.4852	-1.2421
	storage	Source	4.90909	2.88875	.222	-2.2125	12.0307
		point of use	-3.45455	2.88875	.465	-10.5761	3.6670
	point of use	Source	8.36364*	2.88875	.019	1.2421	15.4852
		Storage	3.45455	2.88875	.465	-3.6670	10.5761

*. The mean difference is significant at the 0.05 level.

Appendix 13 Correlation of physico-chemical and bacteriological parameters for source, storage and point of use

Parameters		Temp.	EC	pH	Turbd.	TDS	TH	NO_3^-	Cl^-	F^-	Mg^{2+}	Fe^{2+}	$PO4^{2-}$	TC
Temp.	Pearson Correlation	1	.372*	-.295	-.312	.382*	-.091	-.071	-.379*	.459**	.068	-.384*	.684**	.039
	Sig. (2-tailed)		.033	.096	.078	.028	.615	.693	.029	.007	.709	.027	.000	.830
	N	33	33	33	33	33	33	33	33	33	33	33	33	33
EC	Pearson Correlation	.372*	1	.152	-.555**	.999**	-.001	-.227	-.304	.349*	-.231	-.459**	.352*	-.093
	Sig. (2-tailed)	.033		.400	.001	.000	.998	.204	.085	.047	.197	.007	.045	.607
	N	33	33	33	33	33	33	33	33	33	33	33	33	33
pH	Pearson Correlation	-.295	.152	1	.173	.146	.393*	-.310	.031	.202	-.062	.263	-.069	-.331
	Sig. (2-tailed)	.096	.400		.337	.418	.024	.079	.863	.260	.733	.139	.701	.060
	N	33	33	33	33	33	33	33	33	33	33	33	33	33
Turbidity	Pearson Correlation	-.312	-.555**	.173	1	-.550**	.534**	.484**	.221	-.333	.451**	.939**	-.333	-.214
	Sig. (2-tailed)	.078	.001	.337		.001	.001	.004	.215	.058	.008	.000	.058	.232
	N	33	33	33	33	33	33	33	33	33	33	33	33	33
TDS	Pearson Correlation	.382*	.999**	.146	-.550**	1	-.006	-.215	-.330	.359*	-.226	-.456**	.360*	-.103
	Sig. (2-tailed)	.028	.000	.418	.001		.975	.229	.061	.040	.207	.008	.039	.567
	N	33	33	33	33	33	33	33	33	33	33	33	33	33
TH	Pearson Correlation	-.091	-.001	.393*	.534**	-.006	1	.098	.327	-.115	.205	.623**	-.084	-.113
	Sig. (2-tailed)	.615	.998	.024	.001	.975		.588	.063	.524	.253	.000	.643	.532
	N	33	33	33	33	33	33	33	33	33	33	33	33	33
NO_3^-	Pearson Correlation	-.071	-.227	-.310	.484**	-.215	.098	1	.130	-.512**	.555**	.442*	-.341	.058
	Sig. (2-tailed)	.693	.204	.079	.004	.229	.588		.469	.002	.001	.010	.052	.747
	N	33	33	33	33	33	33	33	33	33	33	33	33	33

Parameters		Temp.	EC	pH	Turbd.	TDS	TH	NO_3^-	Cl^-	F^-	Mg^{2+}	Fe^{2+}	$PO4^{2+}$	TC
Cl^-	Pearson Correlation	-.379*	-.304	.031	.221	-.330	.327	.130	1	-.675**	.271	.255	-.509**	.256
	Sig. (2-tailed)	.029	.085	.863	.215	.061	.063	.469		.000	.127	.152	.002	.150
	N	33	33	33	33	33	33	33	33	33	33	33	33	33
F^-	Pearson Correlation	.459**	.349*	.202	-.333	.359*	-.115	-.512**	-.675**	1	-.298	-.279	.731**	-.408*
	Sig. (2-tailed)	.007	.047	.260	.058	.040	.524	.002	.000		.093	.116	.000	.019
	N	33	33	33	33	33	33	33	33	33	33	33	33	33
Mg^{2+}	Pearson Correlation	.068	-.231	-.062	.451**	-.226	.205	.555**	.271	-.298	1	.424*	-.046	-.082
	Sig. (2-tailed)	.709	.197	.733	.008	.207	.253	.001	.127	.093		.014	.798	.652
	N	33	33	33	33	33	33	33	33	33	33	33	33	33
Fe^{2+}	Pearson Correlation	-.384*	-.459**	.263	.939**	-.456**	.623**	.442*	.255	-.279	.424*	1	-.379*	-.324
	Sig. (2-tailed)	.027	.007	.139	.000	.008	.000	.010	.152	.116	.014		.029	.066
	N	33	33	33	33	33	33	33	33	33	33	33	33	33
$PO4^{2-}$	Pearson Correlation	.684**	.352*	-.069	-.333	.360*	-.084	-.341	-.509**	.731**	-.046	-.379*	1	-.077
	Sig. (2-tailed)	.000	.045	.701	.058	.039	.643	.052	.002	.000	.798	.029		.671
	N	33	33	33	33	33	33	33	33	33	33	33	33	33
TC	Pearson Correlation	.039	-.093	-.331	-.214	-.103	-.113	.058	.256	-.408*	-.082	-.324	-.077	1
	Sig. (2-tailed)	.830	.607	.060	.232	.567	.532	.747	.150	.019	.652	.066	.671	
	N	33	33	33	33	33	33	33	33	33	33	33	33	33

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix 14 Dry season measurement

Parameters	Shamba kebele			Anchitochawkare kebele			Bolelachawkare kebele			Zaminenare k.	
	SW	HDW	SS	SW	HDW	SS	SW	HDW	SS	MS	LS
Temp.	24	22	23	22	23	22	23	22	22	26	27
EC	137.9	81	60.5	112.3	136.6	70.4	95.5	92.5	90.3	116.5	118
PH	8	5.8	6.8	8	6.9	7.6	8.3	8.5	6.7	6.12	6.7
Turbidity	1.79	11.1	49	1.96	0.65	22	1.2	42.3	0.57	1.8	2.8
TDS	92.3	54.3	40.5	75.2	91.5	47.3	61.7	63.9	60.5	78	79.2
TH ($CaCO_3$)	60	26	65	34	26	22	56	95	102	22	38
Nitrate	1.36	3.3	3.74	2.55	2.5	1.4	1.45	1.36	1.1	1.54	1.1
Chloride	7.5	8.15	8.8	6.4	7.1	7.8	8.9	7.4	9.5	6.38	5.8
Fluoride	0.7	0.4	0.25	0.9	0.3	0.6	0.65	0.75	0.4	1.15	0.95
Magnesium	11	12.9	13	9.3	10.5	11.5	13	11	13.5	9.5	9
Iron	0.03	0.09	0.2	0.05	0.02	0.08	0.05	0.2	0.03	0.02	0.01
Phosphate	0.72	0.34	0.4	0.46	0.2	0.34	0.4	0.36	0.32	0.61	0.8
E.coli/TTC	10	5	10	4	15	5	15	2	17	7	15

Appendix 15 Wet season measurement

Parameters	Shamba kebele			Anchitochawkare kebele			Bolelachawkare kebele			Zaminenare k.	
	SW	HDW	SS	SW	HDW	SS	SW	HDW	SS	MS	LS
Temp.	22.5	21.5	22	21	21	20	22.5	20	20	25	26.5
EC	127	75	55	102	130	60.4	90	82.5	84.4	105.5	108.5
PH	7.5	5.7	6.2	7.5	6.5	7	8	8.2	6.5	6	6.5
Turbidity	3.3	19.1	67.5	3.4	1.8	38	1.8	52.5	3	2	2
TDS	85	50.2	36.8	68.34	87.1	40.4	60.3	55.2	56.5	70.6	72.6
TH ($CaCO_3$)	55	20	59	31	21	18	50	87	94	18	35
Nitrate	2.2	3.5	3.87	2.6	2.8	1.8	1.5	1.4	1.3	1.55	1.2
Chloride	7.8	8.5	8.9	6.3	7	8	9	7.8	9.8	6.4	6
Fluoride	0.7	0.35	0.23	0.9	0.3	0.55	0.65	0.73	0.35	1.1	0.95
Magnesium	11	11.5	12.5	9	10	11	12.5	10.5	13	9.5	8
Iron	0.04	0.1	0.25	0.08	0.05	0.08	0.07	0.2	0.03	0.02	0.01
Phosphate	0.78	0.5	0.5	0.48	0.3	0.45	0.5	0.4	0.4	0.64	0.9
E.coli/TTC	12	9	17	5	21	11	22	7	25	8	18

Appendix 16 Descriptive values of dry and wet seasons

Parameters		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Maximum
						Lower	Upper Bound		
Temperature	Dry	11	23.2727	1.73729	.52381	22.1056	24.4399	22.00	27.00
	Wet	11	22.0000	2.09762	.63246	20.5908	23.4092	20.00	26.50
	Total	22	22.6364	1.98915	.42409	21.7544	23.5183	20.00	27.00
EC	Dry	11	101.0455	25.45484	7.67492	83.9447	118.1462	60.50	137.9
	Wet	11	92.7545	24.54752	7.40136	76.2633	109.2458	55.00	130.0
	Total	22	96.9000	24.76880	5.28073	85.9181	107.8819	55.00	137.9
pH	Dry	11	7.2200	.90620	.27323	6.6112	7.8288	5.80	8.50
	Wet	11	6.8727	.82715	.24940	6.3170	7.4284	5.70	8.20
	Total	22	7.0464	.86512	.18444	6.6628	7.4299	5.70	8.50
Turbidity	Dry	11	12.1973	17.82331	5.37393	.2234	24.1711	.57	49.00
	Wet	11	17.6273	23.86852	7.19663	1.5922	33.6624	1.80	67.50
	Total	22	14.9123	20.74325	4.42248	5.7152	24.1093	.57	67.50
TDS	Dry	11	67.6091	17.06701	5.14590	56.1433	79.0749	40.50	92.30
	Wet	11	62.0945	16.44885	4.95952	51.0441	73.1450	36.80	87.10
	Total	22	64.8518	16.59853	3.53882	57.4924	72.2112	36.80	92.30
TH	Dry	11	49.6364	28.65056	8.63847	30.3887	68.8841	22.00	102.0
	Wet	11	44.3636	27.27003	8.22222	26.0434	62.6839	18.00	94.00
	Total	22	47.0000	27.42783	5.84763	34.8392	59.1608	18.00	102.0
Nitrate	Dry	11	1.9455	.92470	.27881	1.3242	2.5667	1.10	3.74
	Wet	11	2.1564	.92198	.27799	1.5370	2.7758	1.20	3.87
	Total	22	2.0509	.90753	.19349	1.6485	2.4533	1.10	3.87
Chloride	Dry	11	7.6391	1.16465	.35116	6.8567	8.4215	5.80	9.50
	Wet	11	7.7455	1.23803	.37328	6.9137	8.5772	6.00	9.80
	Total	22	7.6923	1.17420	.25034	7.1717	8.2129	5.80	9.80
Fluoride	Dry	11	.6409	.28707	.08655	.4481	.8338	.25	1.15
	Wet	11	.6145	.29008	.08746	.4197	.8094	.23	1.10
	Total	22	.6277	.28195	.06011	.5027	.7527	.23	1.15
Iron	Dry	11	.0709	.06848	.02065	.0249	.1169	.01	.20
	Wet	11	.1418	.19989	.06027	.0075	.2761	.01	.70
	Total	22	.1064	.15026	.03203	.0397	.1730	.01	.70
Magnesium	Dry	11	11.2455	1.55201	.46795	10.2028	12.2881	9.00	13.50
	Wet	11	10.9545	1.31253	.39574	10.0728	11.8363	9.00	13.00
	Total	22	11.1000	1.41050	.30072	10.4746	11.7254	9.00	13.50
Phosphate	Dry	11	.4500	.18379	.05542	.3265	.5735	.20	.80
	Wet	11	.5318	.17600	.05307	.4136	.6501	.30	.90
	Total	22	.4909	.18053	.03849	.4109	.5709	.20	.90
TC	Dry	11	9.5455	5.29837	1.59752	5.9860	13.1049	2.00	17.00
	Wet	11	14.0909	6.80374	2.05141	9.5201	18.6617	5.00	25.00
	Total	22	11.8182	6.38925	1.36219	8.9853	14.6510	2.00	25.00

Appendix 17 ANOVA results for dry and wet seasons

		Sum of Squares	Df	Mean Square	F	Sig.
Temperature	Between Groups	8.909	1	8.909	2.402	.137
	Within Groups	74.182	20	3.709		
	Total	83.091	21			
EC	Between Groups	378.065	1	378.065	.605	.446
	Within Groups	12505.295	20	625.265		
	Total	12883.360	21			
Ph	Between Groups	.663	1	.663	.881	.359
	Within Groups	15.054	20	.753		
	Total	15.717	21			
Turbidity	Between Groups	162.167	1	162.167	.365	.552
	Within Groups	8873.767	20	443.688		
	Total	9035.934	21			
TDS	Between Groups	167.256	1	167.256	.595	.449
	Within Groups	5618.476	20	280.924		
	Total	5785.733	21			
TH	Between Groups	152.909	1	152.909	.195	.663
	Within Groups	15645.091	20	782.255		
	Total	15798.000	21			
Nitrate	Between Groups	.245	1	.245	.287	.598
	Within Groups	17.051	20	.853		
	Total	17.296	21			
Chloride	Between Groups	.062	1	.062	.043	.838
	Within Groups	28.891	20	1.445		
	Total	28.954	21			
Fluoride	Between Groups	.004	1	.004	.046	.833
	Within Groups	1.666	20	.083		
	Total	1.669	21			
Iron	Between Groups	.028	1	.028	1.239	.279
	Within Groups	.446	20	.022		
	Total	.474	21			
Magnesium	Between Groups	.465	1	.465	.225	.640
	Within Groups	41.315	20	2.066		
	Total	41.780	21			
Phosphate	Between Groups	.037	1	.037	1.137	.299
	Within Groups	.648	20	.032		
	Total	.684	21			
TC	Between Groups	113.636	1	113.636	3.056	.096
	Within Groups	743.636	20	37.182		
	Total	857.273	21			

Appendix 18 Correlations result for sanitation and hygiene

		type of latrine	disposing of waste	habit of using latrine	washing hands	existence of latrine
type of latrine	Pearson Correlation	1				
	Sig. (2-tailed)					
	N	83				
disposing of waste	Pearson Correlation	.598**	1			
	Sig. (2-tailed)	.000				
	N	83	83			
habit of using latrine	Pearson Correlation	.833**	.827**	1		
	Sig. (2-tailed)	.000	.000			
	N	83	83	83		
washing hands	Pearson Correlation	.824**	.848**	.950**	1	
	Sig. (2-tailed)	.000	.000	.000		
	N	83	83	83	83	
existence of latrine	Pearson Correlation	.244*	.409**	.338**	.364**	1
	Sig. (2-tailed)	.026*	.000	.002*	.001	
	N	83	83	83	83	83

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

BIOGRAPHICAL SKETCH

Meseret Bekele was born in Sodo Town, Wolaita Zone, Southern Ethiopia. He attended high school education at Sodo secondary and preparatory school. He then joined Wolaita Sodo University, college of Agriculture and Natural Resources and graduated with Bachelor of Science Degree in Natural Resources Management with a status of great distinction in 2011. After enormous commitment and hard work, he continued his studies in a Master's program at school of Biosystems and Environmental Engineering, specialization in *Water Resource Engineering and Management*, Institute of Technology of Hawassa University in mid of 2015.